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REPORT ON

CLARION RIVER POLLUTION ABATEMENT

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SANITARY WATER BOARD

Commonwealth of Pennsylvania
DEPARTMENT OF HEALTH
HARRISBURG
March, 1949

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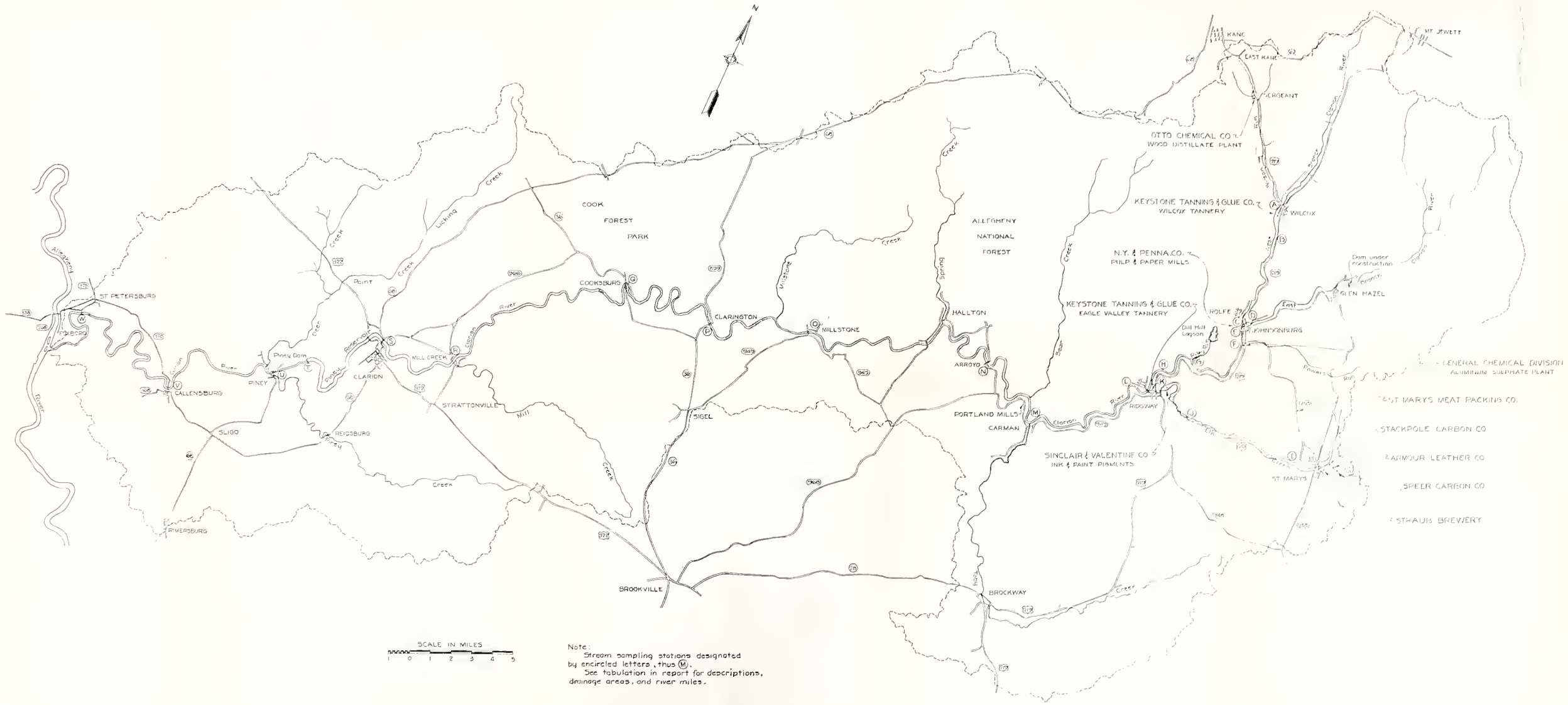

Note:
Stream sampling stations designated by encircled letters, thus (M).
See tabulation in report for descriptions, drainage areas, and river miles.

FIGURE 1. MAP OF CLARION RIVER BASIN

REPORT ON

CLARION RIVER POLLUTION ABATEMENT

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By

CAMP, DRESSER & McKEE

Consulting Engineers

BOSTON • MASSACHUSETTS

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COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF HEALTH
SANITARY WATER BOARD

NOTICE OF ACCEPTANCE

The Sanitary Water Board has accepted this report as fulfillment by Camp, Dresser and McKee of its contract with the Board for the Clarion River Survey as setting forth the considered engineering opinions and recommendations of the consultants. It does not necessarily reflect the opinions and policies of the Board.

Norris W. Vaux

Norris W. Vaux, M. D.
Secretary of Health
Chairman, Sanitary Water Board

July 21, 1949

CAMP, DRESSER & McKEE
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March 31, 1949

Sanitary Water Board
Dr. Norris W. Vaux, Chairman
Pennsylvania Department of Health
Harrisburg, Pennsylvania

Report on Clarion River Pollution Abatement

Gentlemen:

In compliance with the terms of our contract with the Commonwealth of Pennsylvania dated August 2, 1948, we have made a comprehensive study of the Clarion River and its tributaries with respect to pollution by the discharge of industrial wastes and we submit herewith a report of our findings and recommendations. The results of our investigations are presented in detail in the main body of this report. Our findings and recommendations are summarized below.

SUMMARY

Pollution by Pennsylvania statute is "noxious and deleterious substances rendering unclean the waters of the Commonwealth to the extent of being harmful or inimical to the public health, or to aquatic life, or to the use of such waters for domestic water supply, or industrial purposes, or for recreation." In order to determine the extent of pollution we have found it necessary to: (1) define the appropriate uses of the Clarion River and its tributaries, (2) establish water quality standards for the waters of the river and its tributaries which are commensurate with these uses, (3) determine the capacity of the waters within the quality standards for the assimilation of harmful material, and (4) determine the quantity of harmful materials entering the streams which is in excess of their powers of assimilation.

Water Quality Standards

We recommend that the Sanitary Water Board establish minimum water quality standards for the waters of the Clarion River and its non-acid tributaries which will permit their use for public and industrial water supply after treatment, for fish propagation, recreation and bathing, and for water power. Our studies indicate that these are reasonable uses of the river waters and will not require unreasonable degrees of pollution abatement. The water quality standards should permit the reasonable use of these

waters for the disposal of sewage and industrial wastes. We recommend that the Sanitary Water Board adopt the standards set forth in Table 1 of Chapter II. These standards are appropriate for the recommended uses of the waters and can be met with practicable pollution-abatement measures.

The Clarion River and its non-acid tributaries are subject to industrial waste discharges from a wood-distillate plant at Sergeant; a tannery at Wilcox; a pulp and paper mill at Johnsonburg; two carbon plants, a tannery and a brewery at St. Marys; and a tannery and ink manufacturing plant at Ridgway. The streams are also subjected to the discharge of sewage from the boroughs of Johnsonburg, St. Marys and Ridgway and from some of the villages.

Nature of the Pollution

All investigations show that pollution by putrescible organic matter is of paramount importance in the Clarion River basin. Putrescible organic matter is fed upon by bacteria in the river waters and in the feeding process the dissolved oxygen in the water is used up at rates approximately proportional to the concentration of organic matter present. When the concentration of organic matter is too great, oxygen may be depleted faster than it can be replenished from the atmosphere and the oxygen level may thus be lowered sufficiently to damage fish life and to cause odor nuisances. Since the depression of the oxygen level is the most important detrimental effect of organic pollutants, the most satisfactory measure of the concentration of organic pollutants is in terms of their biochemical oxygen demand (BOD) and the best means of determining the extent of organic pollution is through studies of the oxygen balance in the streams.

Contributors of Putrescible Organic Matter

Various surveys of the Clarion River performed during the past three years, including our own, show that an overwhelming portion of the total amount of putrescible organic matter which has been discharged into the Clarion River has been contributed by the New York and Pennsylvania Com-

Source of Organic Loading	*Approximate 5-day 20°C BOD in lbs per day*	*Population Equivalent @ 0.2 lbs per day per person*	*% of total*
New York and Pennsylvania Company Johnsonburg	81,500*	407,500	92.87
Borough of St. Marys	1,640	8,200	1.87
Eagle Valley Tannery, Ridgway	1,330	6,650	1.51
Borough of Ridgway	1,300	6,500	1.48
Borough of Johnsonburg	1,000	5,000	1.14
Wilcox Tannery, Wilcox	385	1,925	0.44
Armour Leather Company, St. Marys	370	1,850	0.42
Straub Brewery, St. Marys	150	750	0.17
Sinclair and Valentine Co., Ridgway	45	225	0.05
Otto Chemical Company, Sergeant (Mondays only)	40	200	0.05
Other Industries and Municipalities	negligible		
Totals	87,760	438,800	100.00

* Based on the average condition of the river during the past three years. All other loadings based on our actual surveys of the wastes.

pany's pulp and paper mill at Johnsonburg. The following table shows the approximate amount of 5-day 20°C BOD added daily by each contributor in the valley. The table indicates that the New York and Pennsylvania Company's pulp and paper mill has been discharging BOD which is equivalent in strength to the sewage from a population of approximately 407,500 and that this organic matter constitutes approximately 93% of the total organic matter which has been discharged to the river.

The above table shows the quantities of organic pollutants which have been discharged to the river and its tributaries. These quantities constitute pollution only to the extent that they render the streams unclean as defined by the law. Extensive measurements and investigations were made to determine the assimilative capacity of the main river and its principal polluted tributaries at the various focal points of pollution. Our studies show that at drought flow conditions the Clarion River and its tributaries are, in our opinion, capable of assimilating without harmful or inimical effects the BOD loads as shown in the following table. Also shown in the table are the actual BOD loadings as measured by analyses of the river waters during the past three years or of the actual wastes discharged.

Stream and Location	*Total Allowable Loading of 5-day BOD in lbs per day*	*Actual Existing Loading of 5-day BOD in lbs per day*
West Branch at Wilcox	911	440
Elk Creek at St. Marys	315	2,190
Clarion River at Johnsonburg	3,370	81,500
Clarion River at Ridgway	3,420	35,400

This table indicates the existence of organic pollution at St. Marys, at Johnsonburg and at Ridgway, but not at Wilcox. Most of the organic pollution at Ridgway is residual pollution from the pulp and paper mill at Johnsonburg.

The Glen Hazel Dam

A new dam is under construction by the U. S. Engineers on the East Branch of the Clarion River near Glen Hazel. This dam is to be used for flood control and low-flow regulation. Its operation is expected to increase the drought flow at Johnsonburg from about 20 cfs to 92 cfs and at Ridgway from about 30 cfs to 102 cfs. The total allowable BOD loading at Johnsonburg will then be about 13,200 lbs per day and at Ridgway about 10,800 lbs per day. Inasmuch as this dam will probably be completed between 1953 and 1955, we recommend that its effect be considered in determining the allowable loadings upon the Clarion River.

Extent of Pollution and Abatement Required

Table 13 in the main body of the report shows the extent of organic pollution and the allowable BOD loadings at each focal point of pollution both with and without consideration of the effect of low-flow regulation by the Glen Hazel dam. The table shows organic pollution at St. Marys, to the extent of 1,875 lbs of BOD per day, which must be removed by pollution-abatement works. The extent of pollution of the Clarion River at Grant Street bridge in Johnsonburg, with credit allowed for the Glen Hazel dam, was found to be approximately 68,300 lbs of BOD per day, all of

which must be removed by the paper mill. If this is accomplished, our studies show that the allowable increment of BOD loading at the mouth of Powers Run, where sewage from the borough of Johnsonburg is to be discharged, will be 1,890 lbs of BOD per day. This is much in excess of the BOD contribution from the borough of Johnsonburg and indicates that biological treatment of the sewage from Johnsonburg is not essential to maintain the water quality standards of the stream. Our studies show that the allowable increment of BOD loading at Ridgway will be 2,530 lbs per day after effective treatment is accomplished at the Johnsonburg pulp and paper mill and dilution is provided by the Glen Hazel dam. The total existing BOD contribution at Ridgway is slightly in excess of this figure and indicates that primary treatment of the municipal sewage will be required for BOD removal. Secondary biological treatment of the municipal sewage is found to be unnecessary.

Our investigation shows that the Clarion River is grossly polluted by suspended solids which during low flows settle out to form unsightly and odoriferous sludge banks in upstream reaches and during high flows are carried into Piney Reservoir. This solid matter derives not only from settleable solids in the wastes, but to a large extent from the synthesis of dissolved organic matter into bacterial bodies and biological slimes which thus become suspended solids. We estimate, for example, that up to 63% of the organic content of sludge banks which have been forming in the river between Johnsonburg and Ridgway may still form after primary sedimentation of the paper mill wastes if no action is taken to reduce the discharge of dissolved organic matter. Effective abatement of pollution by solids is thus seen to be closely related to removal of the total organic matter including that which is dissolved. Approximately 75% of the organic matter in the river water at the Grant Street bridge was found to be dissolved.

Piney Reservoir

Piney Reservoir constitutes a huge catch-all or settling basin for all original and synthesized settleable organic solids. The sludge deposits which have accumulated in the reservoir since its construction in 1924 undergo slow bacterial decomposition and in so doing exude BOD to the overlying waters. As a result, the dissolved-oxygen content of the waters passing through the reservoir is seriously decreased during dry seasons. Consideration is now being given by the U. S. Engineers to the construction of a new huge dam and reservoir upstream from Piney Reservoir. Unless and until pollution from the paper mill is abated to the extent recommended in this report, such a reservoir would reduce natural purification processes and seriously degrade the quality of the river waters. Our studies indicate, however, that such a reservoir can be constructed and used without impairment of water quality if the recommendations for pollution abatement contained in this report are followed.

Secondary Effects

The taste, odor and appearance of the waters of the Clarion River and Elk Creek are below the standards recommended for water quality and pollution therefore exists with respect to these characteristics at present. Most of these characteristics are attributable to organic matter associated with BOD. When effective abatement of pollution with respect to BOD is

achieved, a considerable improvement may be expected with respect to taste, odor and appearance. Further corrective measures specifically for taste and odor control, other than those recommended in this report, are not recommended until a definite need for such measures can be shown.

Focal Points of Pollution

Our investigation reveals that the Clarion River and its tributaries are polluted at five focal points. Each of these focal points is treated in detail in a chapter in the main body of the report and specific recommendations are made for abatement at each point, with estimates of cost of construction and operation if the required abatement measures are significant. The two most important focal points of pollution are at Johnsonburg and at St. Marys. Our findings with respect to these points are summarized below.

New York and Pennsylvania Company, Johnsonburg

The plant of the New York and Pennsylvania Company at Johnsonburg comprises a soda pulp mill, a sulfite pulp mill, an old-paper (de-inking) department and a paper mill. At the time of our survey of the wastes from the various processes in these mills, the total 5-day BOD load being discharged to the stream (exclusive of old-paper wastes) was about 45,000 lbs per day, of which about 41,000 lbs per day emanated from the main ditch. The discrepancy between these figures and the 81,500 lbs per day indicated by various river water analyses is attributable to overflows from the soda mill and to the break-downs or clean-ups in the sulfite mill. Since the time of our survey a new counter-current pulp washer has been installed in the soda mill which should virtually eliminate all strong soda wastes. Moreover, displacement pulp washing has been instituted in the sulfite mill which has reduced the BOD load in the main ditch to about 24,000 lbs per day.

When all of the measures which the New York and Pennsylvania Company has planned or proposed for pollution abatement are completed and in operation and when all break-down and overflow wastes are eliminated, we estimate that the 5-day BOD load on the river at Johnsonburg will be about 17,000 lbs per day. This is still in excess of the assimilative capacity of the river even after the Glen Hazel dam is operating to improve low stream flows. It will be necessary, therefore, to achieve further reduction of BOD either by changes in processes or by further treating the wastes.

The principal source of organic pollution in the mill is the weak sulfite waste liquor (SWL) from the blow pits which accounts for about 46% of the BOD in the main ditch with the present displacement washing of sulfite pulp. The SWL is also the principal contributor to tastes and odors in the river waters. If this weak SWL can be substantially eliminated by highly effective counter-current washing of sulfite pulp, and if break-down and overflow wastes are eliminated, we estimate that after all presently planned works are in operation the 5-day BOD loading on the river can be reduced to about 7,000 lbs per day. This is well within the assimilative capacity of the stream with respect to BOD after low-flow regulation is effected by the dam. In our judgment it is not practicable or economical to endeavor to reduce the BOD loading at the paper mill to 3,370 lbs per day, the assimilative capacity of the river, without credit for low-flow regulation from the new dam.

The question may arise as to the necessity of reducing the BOD loading to 7,000 lbs per day when 13,200 lbs per day will suffice to maintain the dissolved-oxygen concentration above 4.0 ppm. The answer lies in the fact that the 7,000-lb limit is based on almost complete removal of SWL, which is necessary to attain reasonably effective abatement of tastes and odors. Our studies show that discernible tastes and odors associated with SWL may still be present in the Clarion River just downstream from Johnsonburg during low flows even with the BOD loading as low as 7,000 lbs per day. If the limit is set at 13,200 lbs of BOD per day, tastes and odors will be more pronounced.

We recommend, therefore, that the New York and Pennsylvania Company be directed to reduce its 5-day BOD load on the Clarion River at Johnsonburg to 7,000 lbs per day or less *at all times*. We recommend that this reduction be accomplished by the presently planned program augmented by the addition of two more stages in the displacement washing system for sulfite pulp and other minor improvements. The cost of the added construction for displacement washing is estimated at $49,800. In the event that the Company is not successful in attempts to obtain adequate BOD reduction by efficient counter-current pulp washing, we recommend that all of the settled main-drain wastes be fortified with nitrogen and phosphorous and then subjected to secondary biological treatment on high-rate trickling filters. The plant required to accomplish the desired removal of BOD with no displacement washing whatsoever is estimated to cost $795,000 and the annual operating cost is estimated at $113,000 including nutrient chemicals, power, added personnel and maintenance. Both the original cost and the annual operating cost of biological treatment can be materially reduced if the present displacement washing system is continued in operation. Other specific recommendations with regard to pollution abatement by the New York and Pennsylvania Company, estimated to cost $138,200, are described in detail in the main body of the report.

Elk Creek at St. Marys

Elk Creek at St. Marys is grossly polluted by organic wastes from the Armour Leather Company tannery and the Straub Brewery and by sewage from the borough. It also receives waste waters containing fine carbon granules from the Speer Carbon Company and the Stackpole Carbon Company. Industrial wastes are discharged upstream from the center of the borough and cause the creek to be unsightly as it passes through the borough. We recommend that all organic pollutants be excluded from Elk Creek and its branches in and above St. Marys and that all carbon plant wastes be given effective treatment. The carbon plants already have treatment works in operation for part of their wastes and have plans prepared to include the remainder. We recommend that these plans be carried out forthwith.

To exclude organic pollutants from the creek in and above St. Marys we recommend that these wastes (except tan liquors) be taken into the sanitary sewers of the borough and be discharged after complete treatment with the sanitary sewage into Elk Creek below the borough. This plan will result in a cleaner stream through the borough than can be attained by separate secondary treatment of the wastes at the tannery and brewery.

The proposed plan for combined treatment with the borough's sewage will also result in savings to the industries and to the borough. The present plan for the construction of treatment works for the sewage alone has been estimated by the borough's consulting engineers to cost $394,000. On the basis of the same unit cost data we estimate that the combined plant will cost $452,000 which should be shared approximately as follows: Borough of St. Marys $370,000, Straub Brewery $23,000, Armour Leather Company $59,000. The operating costs should also be shared equitably as outlined in the main body of the report. The resulting cost to the borough of construction and operation will be less than would be the case for separate treatment of its sewage.

Most of the tan liquors from the Armour Leather Company tannery at St. Marys are currently trucked to Ridgway for evaporation and disposal by the Keystone Tanning and Glue Company with other tan liquors. We recommend that the tan liquors be kept out of the streams altogether either by a continuation of the present arrangement or by separate disposal by the Armour Leather Company in a similar manner.

Municipal Sewage

Our investigation shows that, except for St. Marys, the sanitary sewage discharged into the river and its tributaries does not constitute a BOD problem and secondary biological treatment of sanitary sewage is not necessary to maintain the water quality standards in the streams. The principal problem with respect to sanitary sewage is bacterial pollution. Primary treatment of sanitary sewage for removal of suspended solids and grease followed by chlorination for disinfection should constitute adequate treatment of the sewage from Johnsonburg and Ridgway. Such treatment is already in effect at Clarion. Similar treatment for the villages should be required when they are sewered. Secondary biological treatment followed by chlorination should be required of the sewage from St. Marys because of the inadequacy of the assimilative capacity of Elk Creek at St. Marys. The problem at St. Marys is summarized in the preceding paragraphs and is discussed in detail in the main body of the report.

Policing by Automatic Recorders

In our judgment, it will be much more difficult to insure the proper and continuous use of the pollution-abatement facilities recommended in this report than it will be to induce the industries to provide the facilities. It is essential, therefore, after the works recommended in this report have been constructed that the Sanitary Water Board have effective means for insuring the continuous and satisfactory use of these works. Periodic inspection and river sample analyses will not suffice because of the probability of sporadic overflows or dumpings of strong industrial wastes. In order to detect such pollution one or more continuous recording stations are necessary to obtain continuous records of the dissolved-oxygen content and BOD content of the river waters. Apparatus satisfactory for these purposes has not yet been developed ready for installation. Portions of the equipment are available but research and development will be required before a complete station can be designed. We recommend that the Sanitary Water Board authorize the necessary research and development and the construction of

one or more stations on the Clarion River. This matter is discussed in more detail in Chapter IX.

Basis of Costs

All cost estimates contained in this report are based upon contractors' bid prices and quotations for equipment which were current about January, 1949. All estimates contain an allowance for engineering and contingencies.

Acknowledgments

We wish to acknowledge with thanks the cooperation and assistance of the engineering staff of the Department of Health. We are particularly indebted to the Industrial Wastes Division for data on past surveys and analyses and for advice and guidance in the conduct of our surveys. We are grateful to the U. S. Public Health Service and to the U. S. Engineers for printed data and information furnished by correspondence relative to the sanitary condition of the Clarion River, stream flows and other hydrometric data. The officials of various industrial plants and boroughs have been most cooperative in our work and have freely furnished us with existing information and data relating to the investigation. We wish to acknowledge the contributions made to the solutions of some of the most difficult problems by Professors Edward W. Moore and Harold A. Thomas of the Harvard Graduate School of Engineering and by Professor Clair N. Sawyer of the Massachusetts Institute of Technology.

Respectfully submitted,

CAMP, DRESSER & MCKEE

By Thomas R. Camp

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF HEALTH
SANITARY WATER BOARD

REPORT ON
CLARION RIVER POLLUTION ABATEMENT

March 31, 1949

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CHAPTER I.

HISTORICAL BACKGROUND

Description of the Clarion River Basin

The Clarion River is formed by the confluence of its East and West Branches at Johnsonburg in Elk County, Pennsylvania, and flows in a southwesterly direction for about 98 river miles to enter the Allegheny River near Parker's Landing about 50 miles northeast of Pittsburgh. The mouth of the Clarion River is 86.1 river miles upstream from the mouth of the Allegheny River. At its mouth the Clarion River has a drainage area of approximately 1,240 sq miles, all of which is in the Commonwealth of Pennsylvania. The salient features of the Clarion River basin are shown on the accompanying map, Fig. 1.

The watershed of the Clarion River is, in general, a dissected plateau of rough topography, with streams flowing in narrow steep-sided valleys without bottom lands. Northeast of Clarion it is heavily forested and unsuited to agriculture. West of Clarion there is much arable land but in recent years strip mining has invaded this area.

The streams have steep slopes and the flow is rapid. From Johnsonburg to its mouth the slope of the Clarion River is relatively uniform and averages approximately 5.8 ft per mile. The slope of the tributaries and branches are much steeper, the West Branch having a slope of about 11 ft per mile below Wilcox, Wilson Run a slope of about 25 ft per mile above Wilcox, and Elk Creek a slope of about 25 ft per mile. The steep slopes are of prime importance in their contribution to the high capacity of the river and its tributaries for the assimilation of putrescible organic matter. The only reservoir of importance is Piney Reservoir on the Clarion River near Clarion which is owned and operated for power purposes by the Pennsylvania Electric Company. A new reservoir for flood control and low-flow regulation is now being constructed by the United States Engineer Department near Glen Hazel on the East Branch of the Clarion River.

Sources of Pollution

The Clarion River and some of its tributaries have been polluted for many years. The principal sources of pollution are industrial wastes but untreated sewage also is discharged from municipalities.

The principal source of pollution by industrial wastes is the pulp and paper mill of the New York and Pennsylvania Company at Johnsonburg. Other possible sources of pollution by industrial wastes are the wood distillate plant of the Otto Chemical Company on Wilson Run near the village of Sergeant, the tannery of the Keystone Tanning and Glue Company at Wilcox on the West Branch of the Clarion River, the alum manufacturing plant of the General Chemical Division of the Allied Chemical and Dye Corporation at Johnsonburg, the tannery of the Keystone Tanning and Glue Company at Ridgway, the carbon parts manufacturing plants of the Speer Carbon Company and the Stackpole Carbon Company at St. Marys on Elk

Creek, the tannery of the Armour Leather Company at St. Marys on the South Branch of Elk Creek, the Straub Brewery at St. Marys on Elk Creek, the Sinclair and Valentine Company plant for the manufacture of colors for printing inks at Ridgway on Elk Creek, and the St. Marys Meat Packing Company on the highway between Johnsonburg and St. Marys.

Untreated sewage is discharged into Wilson Run from private sewers in the village of Sergeant (population 250, 1940 census), into the West Branch from private sewers in the village of Wilcox (population 1,000, 1940 census), into the Clarion River from Johnsonburg (population 4,955, 1940 census), into the Clarion River from Ridgway (population 6,253, 1940 census), and into Elk Creek from St. Marys (population 7,653, 1940 census). Clarion (population 3,798, 1940 census) on the Clarion River discharges the effluent from a primary sewage treatment plant after chlorination. Sanitary sewage is also discharged into Toby Creek and its tributaries from Brockway and nearby villages, but Toby Creek receives acid mine drainage and has been designated as an acid stream under the law. As such, it is specifically excluded from our studies. The South Branch of Elk Creek at St. Marys also receives acid mine drainage, but the amount of acid is insufficient to be important on Elk Creek below the confluence of the branches. Piney Creek and other smaller tributaries in the lower valley are acid streams, but their acidity has little effect on the main river and they apparently receive no polluting organic substances.

Past Sanitary Surveys and Analyses

The Pennsylvania Department of Health made sanitary surveys and analyses of the river waters in 1935 and 1936. Sanitary surveys and analyses were also made, by the Department, of both the river waters and the industrial wastes in 1941 and again in 1946. The results from these surveys, all of which show gross pollution, have been made available to us and have been used in our investigation.

The U. S. Public Health Service made a sanitary survey and analyses of the waters of the Clarion River and its tributaries in 1940. The results of this investigation were published in Part II of the Report of the U. S. Public Health Service on the Ohio River Pollution Control, House Document No. 266 of the 78th Congress, First Session. Laboratory analytical data on the quality of the waters of the Clarion River and its tributaries are contained in this report. The U. S. Public Health Service reported that the Clarion River and its tributaries received wastes with a population equivalent of 147,000, of which more than 80% was from a pulp and paper mill and several tanneries located in the upper part of the drainage area. The report stated that downstream water plants on the Allegheny River have experienced taste, odor and color troubles, apparently attributable to these industrial wastes, at times when a rapid drawdown of Piney Reservoir coincided with a low flow period on the Allegheny River. Local oxygen depletion on the Clarion River was found to be common during the warm months as far downstream as Piney Dam. It was reported that the fish in Piney Reservoir and downstream from Piney Dam were said to be inedible because of the obnoxious taste of the flesh.

The Clarion River has long been considered in connection with proposed flood control reservoirs for the protection of the Ohio River valley. Studies were made by the Flood Commission of Pittsburgh in 1911 of four reser-

voir sites on the Clarion River. Reservoir No. 3 with a dam just below the mouth of Mill Creek is described in the report of the Commission as being the least costly per million cubic feet of storage of any of the projects in the entire Allegheny basin. The reservoir sites on the lower Clarion River were again studied for flood control by the U. S. Engineer Department in 1941. The Engineer Department was advised against sites on the lower Clarion River by the U. S. Public Health Service in the report under date of April 1941 because a reservoir on the lower Clarion River would impound polluted water and thus degrade a section of the stream which was already in unsatisfactory condition. Consideration is still being given, however, to the excellent dam sites in the lower Clarion River valley, and especially to a huge multiple-purpose dam near Mill Creek.

In 1944 studies were made by the U. S. Engineer Department for a multiple-purpose reservoir on the East Branch of the Clarion River, primarily for flood control purposes but also for pollution abatement by low-flow regulation of the Clarion River. A report was made by the Public Health Service under date of February 1945 to the Engineer Department on the sanitary aspects of this reservoir. This report contains the results of laboratory analyses of the waters of the Clarion River and its tributaries and contains estimates of the pollution load. The report also evaluates the pollution abatement benefits of the proposed reservoir. This reservoir is now under construction and should be completed within the next few years.

It was stated in the Public Health Service report of February, 1945, to the U. S. Engineer Department that the total pollution load on the Clarion River was equivalent to the sewage from 81,700 persons of which the pollution from industrial wastes was equivalent to 58,700 persons. The pollution load at Johnsonburg, as reported by industry, was equivalent to 48,000 persons but the stream sampling results indicated that the pollution load was much greater at the time of sampling. The report further stated that *one of the principal shortcomings of the pollution abatement program by industries is not the reduction in pollution under favorable circumstances but is the fact that full effectiveness is secured only part of the time thus in large measure nullifying much of the progress that has been made. For example, there is a large discrepancy,* the report stated, *between the pollution reduction claims made by industry and the actual results obtained by stream sampling programs conducted at apparently unfavorable times as far as industrial waste pollution abatement measures are concerned. Although pollution abatement expenditures of considerable magnitude had been made, the evidence did not reflect dependability of corrective measures in operation.* In support of the proposed East Branch Reservoir, the report stated that increased flows are highly desirable during periods of very low stream flow and will accomplish a pollution abatement that can be accomplished by no other means.

At the public hearing held by the U. S. Engineer Department on January 23, 1945 relative to the proposed East Branch Reservoir, M. LeBosquet, Jr., representing the U. S. Public Health Service, stated that the cost of the reservoir could not be justified for flood control alone but could be justified if pollution abatement benefits are included. He stated, however, that the pollution abatement benefits could not be realized without further pollution abatement measures by local interests. One of the purposes of the hearing

was to explore the willingness and ability of local interests to take further pollution abatement measures within a reasonable time. Mr. LeBosquet further stated that *the requirements in regard to degree of sewage and industrial waste treatment have not been definitely set, but in general the War Department and the Public Health Service working with the War Department will be guided by the requirements of the Sanitary Water Board of Pennsylvania.*

The New York and Pennsylvania Company has collected and analyzed Clarion River water samples since 1937. The flood of 1942 is reported to have damaged or destroyed the Company's records of the river analyses prior to that time. The work was curtailed somewhat between 1942 and 1946 because of the war but complete results are available for 1947 and most of the record for 1948 was made available to us. A prepared statement by the Castanea Paper Company (now the New York and Pennsylvania Company) dated January 16, 1945 was included in the records of the War Department hearing of January 23, 1945 on the East Branch Reservoir. In this statement, the Company committed itself to a policy whereby "it will maintain all of the present measures for abatement of stream pollution, that it will not use the regulated flow of the river as a reason for abandoning efforts to improve the pollution situation, and that it will procede with the necessary installations and processes to abate pollution as rapidly as technical and economical developments of the art permit." The statement included an itemized list of installations made since 1938 and costing $1,283,000, which the Company claimed were made wholly or in part for pollution abatement.

Most of the results of the previously described sanitary surveys and analyses have been made available to us and have been studied in our investigation. All of these surveys indicate gross pollution of the Clarion River and some of its tributaries, and the more recent surveys indicate some progress toward abatement. None of the previous studies were sufficiently complete to be used as a basis for determining the amount of pollution abatement required to restore the quality of the waters.

Program of the Sanitary Water Board

Under the provisions of Pamphlet Laws 1987 of 1937 and the amendments provided by Pamphlet Laws 435 of 1945, the Sanitary Water Board in the Department of Health is authorized to establish standards of purity of the waters of the Commonwealth of Pennsylvania for the protection of public health, animal and aquatic life and for industrial consumption and recreation, and is empowered to order the abatement of pollution of the waters by sewage and industrial wastes and to determine the time for compliance with the provisions of the orders. The law defines pollution to mean "noxious and deleterious substances rendering unclean the waters of the Commonwealth to the extent of being harmful and inimical to the public health or to animal or aquatic life or to the use of such waters for domestic water supply or industrial purposes or for recreation."

During 1944 the Sanitary Water Board held hearings throughout the Commonwealth to announce its program of stream improvement and to permit all interested parties to present their views. At these hearings the Board announced that as a minimum requisite in the protection of the streams of the Commonwealth primary treatment would be required of all sewage discharged to streams except those heavily impregnated with acid

coal-mine drainage. The provisions of the law do not apply to streams polluted by acid mine drainage until such time as, in the opinion of the Board, practical means for the removal of the polluting properties of such drainage shall become known. The law also provides that the discharge of sewage into a stream impregnated with acid coal-mine drainings be permitted when the discharge of sewage does not create a condition inimical to the public interest. At the hearings the Board also announced that, where streams are generally clean, where the streams are so small or the pollution load so heavy or where the protection of a water supply requires it, to give proper protection to the public interest in these streams, complete treatment of sewage is to be specified. It was also announced that simultaneously industries would be required to treat their wastes to a comparable degree where methods for such treatment are known and where they are not known the industries would be expected to develop them with dispatch.

Board Action on the Clarion River

In carrying out its program the Board officially notified about 200 municipalities of the Commonwealth to submit on or before December 31, 1945 detailed construction plans for the required degree of treatment. Notices were subsequently sent to other municipalities and numerous industries throughout the Commonwealth. Primary treatment has generally been defined as treatment by sedimentation to remove the settleable solids and floating materials and about 35% of the putrescible organic matter. Complete treatment has been defined in general as treatment which would accomplish the removal of approximately 85% of the putrescible organic matter. In the official notices which were sent to the alleged polluters on the Clarion River and its tributaries the Board indicated its desire for removals of pollutants which would be equivalent to that obtained by complete treatment of municipal sewage.

At the hearing by the U. S. Engineer Department held at Ridgway on January 23, 1945 relative to the proposed East Branch Reservoir the Sanitary Water Board presented a brief in which it was stated that the pulp and paper mill at Johnsonburg is so predominantly the source of pollution of the Clarion River that it produces approximately three-quarters of the total pollution load. It was stated that the extent of the pollution abatement will primarily depend upon that attainable at the pulp and paper mill and this in turn depends upon the results of investigations on the treatment of these wastes. The Board stated that it would insist that there be the maximum reduction possible by the use of the best practical waste treatment works available under present knowledge. It was further stated by the Board that it was believed that the improvements contemplated by the Board plus the possible low-flow augmentation through multiple-use reservoirs supplemented by the natural biological processes in the stream would make the Clarion River fit for recreational use beginning at some point upstream from Hallton, the point at which the Board felt its own stream abatement program will render the stream of recreational use. The Board also stated that although the net effect of the Board's requirement of treatment of their sewage by the municipalities will be relatively small, such treatment is to be required as a matter of equity in order that all parties responsible for pollution will make an equivalent contribution to the program.

A permit was issued by the Sanitary Water Board in 1943 for inter-

mediate sewage treatment works for Johnsonburg to care for the municipal sewage. No order has been issued for construction. In 1947 the Board authorized the issuance of a permit for complete sewage treatment works for Ridgway, for which plans are complete but construction has not yet started. A notice was issued by the Board to St. Marys in 1945 for complete sewage treatment works. Plans have been prepared but construction has not yet started. Clarion operates works for primary treatment and chlorination of all municipal sewage under a permit from the Board issued in 1942.

As a part of its program for abatement of pollution by industrial wastes the Sanitary Water Board issued a notice to the Otto Chemical Company in 1948 and the company submitted plans for a closed system. Notice was issued by the Board to the Keystone Tanning and Glue Company in 1946 to provide treatment works for the tannery wastes at Wilcox and Ridgway which would effect removals equivalent to those obtained by complete treatment of municipal sewage. A certificate of compliance was issued to this company for both plants on May 12, 1937. The waste treatment works of these plants are reported to effect a reduction of pollution from the raw wastes of approximately 85%. This reduction has been accepted by the Board as compliance with the notice issued in 1946. No official notices were sent to the Speer Carbon Company and the Stackpole Carbon Company at St. Marys, but both companies have voluntarily constructed, or plan to construct, treatment works which have been approved and are now partially in operation. The waste treatment works for the tannery of the Armour Leather Company at St. Marys is being operated under a letter permit dated December 20, 1935. A formal notice was sent to the company in 1946 but no new permit has been applied for. The Sinclair and Valentine Company at Ridgway is operating treatment works authorized under a permit dated February 29, 1948.

The New York and Pennsylvania Company was issued a formal notice on February 18, 1946 to effect a reduction of pollution at its Johnsonburg mill equivalent to complete treatment of municipal sewage. Previous to the issuance of the formal notice a certificate of compliance was issued to the company on November 25, 1936 for the evaporation of its sulfite waste liquors. Because of the size of the problem at the Johnsonburg mill, individual permits have been issued as treatment was proposed for individual wastes. Five such permits have so far been issued. They are as follows:

(1) August 23, 1938. Permit for Dill Hill lagoon for de-inking wastes.
(2) August 28, 1947. Permit for Cyclator for treatment of white waters.
(3) August 28, 1947. Permit for trial sedimentation basin for treatment of wastes from main drain.
(4) November 6, 1947. Permit for Valley lagoon for surplus sulfite waste liquors.
(5) November 24, 1948. Permit for Black Ash lagoon for black ash wastes.

The company was given until January 1, 1949, to submit plans for treatment of all the remaining wastes in the main drain.

Purpose of This Investigation

In order to expedite the pollution abatement program on the Clarion River, the Sanitary Water Board entered into a contract under date of May

17, 1948, with Camp, Dresser & McKee, Consulting Engineers of Boston, the authors of this report, for a preliminary inspection of the Clarion River basin to determine the extent of engineering services required for a report on a comprehensive pollution abatement program in the Clarion River basin. As a result of the preliminary inspection a subsequent contract was entered into under date of August 2, 1948, for a comprehensive study of the Clarion River and its tributaries with respect to pollution by industrial wastes. The contract provided that the Engineers' report should embody specific findings and recommendations with respect to the following:

(a) The amount and kinds of polluting industrial wastes now being discharged into said waters by the New York and Pennsylvania Company's mill at Johnsonburg, Elk County, Pennsylvania, particularly with reference to the character, quantity and strength of such wastes in order to determine the maximum extent to which the said pollution can be reduced by known technical methods, the extent to which the aforesaid company is doing this and the extent to which it is reasonable to require the said company further to treat its wastes, to be demonstrated by functional designs, cost estimates and other data pertaining thereto.

(b) The existence of sources of pollution caused by the discharge of industrial wastes by other industries into said waters, the maximum extent to which the pollution can be reduced by known technical methods, the extent to which this is currently being done and the extent to which it is reasonable to require further treatment of such wastes, to be demonstrated by data pertaining thereto.

Establishing Basis on Which to Work

In order to determine the extent of pollution and the extent to which it is reasonable to require the industries further to treat their wastes, it is essential to (1) define the appropriate uses of the Clarion River and its tributaries, (2) establish water quality standards for the waters of the river and its tributaries which are commensurate with these uses, (3) determine the capacity of the waters for the assimilation of harmful material within the limits of the water quality standards, (4) determine the quantity of harmful materials now entering the streams which is in excess of their powers of assimilation, and (5) determine feasible and economical means whereby these excess quantities of harmful materials may be kept out of the Clarion River and its tributaries. Inasmuch as pollution is defined by law, the Sanitary Water Board should not require removal of harmful materials in excess of that necessary to prevent pollution as so defined. If the quality of the waters meets the standards required for the designated use of these waters there is no pollution, even though the waters contain substances which in higher concentrations would cause pollution.

We have found it necessary both from an engineering standpoint and from a legal standpoint to give consideration in our investigation to the assimilating power of the waters. The assimilating capacity of the waters is of importance and must be so considered if a reasonable and economical pollution abatement program is to be developed. We have found it necessary, moreover, to study all of the wastes entering the streams including municipal sewage in order to recommend joint treatment where it is economical

and feasible and in order to avoid treatment of any waste where treatment is found to be unnecessary.

Current Policy of the Board

The current policy of the Sanitary Water Board with respect to pollution abatement in the Clarion River basin is to require complete treatment by all parties discharging harmful wastes. This policy was established as a matter of equity in order that all parties responsible for pollution might make an equivalent contribution to the program for abatement. The policy was established before the Board had sufficient information on the assimilating capacity of the streams to determine the extent of pollution and whether all parties could make an equivalent contribution by such a program. As will be shown hereinafter, if the required abatement of organic pollution is effected at the main sources of pollution, no contribution can be made to abatement of organic pollution at some of the other points where complete treatment has been ordered by the Board. In the sense that pollution is caused by putrescible organic matter, no pollution, in our opinion, will exist at these points. Bacterial pollution, however, will continue to exist unless all municipal sewage is effectively chlorinated. We recommend, therefore, that the Sanitary Water Board be prepared to modify its policy to accord with our findings in the Clarion River basin to the end that effective pollution abatement may be obtained at less overall cost.

CHAPTER II.

WATER QUALITY STANDARDS FOR CLARION RIVER AND TRIBUTARIES

In order to determine the degree of pollution and the amount of abatement required, the appropriate uses of the waters of the Clarion River and its tributaries and the limiting standards of water quality commensurate with such uses must be established. The principal uses of our public waters are for: (1) public water supply, (2) fish propagation, (3) recreation and bathing, (4) industrial water supply, (5) agriculture, (6) water power, (7) navigation and (8) disposal of sewage and industrial wastes. These uses are listed in the general order of decreasing water quality requirements but not in order of economic importance. Some of these uses are mutually antagonistic and the standards of water quality to be established will depend upon the weight given to the higher uses.

Uses of the Clarion River and Its Tributaries

No water is taken directly from the Clarion River or its tributaries for use as a public water supply. Some of the Clarion River water is used after admixture with the Allegheny River water and following filtration as a public water supply for the city of Pittsburgh. Occasional taste and odor difficulties with the Pittsburgh water have been attributed, at least in part, to the Clarion River water. The Clarion Water Company supplies the borough of Clarion from drilled wells near the Clarion River. The water from the wells is treated in a rapid sand filtration plant for removal of iron and manganese, partial softening and disinfection. Consideration is being given to the advisability of using some water directly from the Clarion River and mixing it with the well water. It is probable that some of the water entering the wells now comes from the river. Considerable difficulty has been experienced at this supply with tastes and odors. Any deleterious substances which are in solution in the river water or which would not be filtered out in passage through the soil to the wells will adversely affect the quality of the well water. There are also several private well supplies along the Clarion River which are affected in the same manner. Some consideration must therefore be given to the use of Clarion River water for drinking purposes in establishing standards of water quality.

The principal uses of the Clarion River water at present are for industrial process water and for the disposal of industrial wastes and sewage. The water is also used to a small extent for water power. The water is so grossly polluted by industrial wastes that its use for water supplies, for fish propagation, recreation and bathing has been seriously impaired. The use of the water for industrial processes and water power is also impaired by the excessive pollution by manufacturing wastes. The discharge of untreated sewage into the waters impairs their use for water supplies and for recreation and bathing because of the intestinal bacteria which are discharged with the sewage.

The Clarion River region is one of the most important hunting and fishing areas in the Commonwealth of Pennsylvania and the Clarion River itself, particularly where it passes through Cook Forest, is an important recreational area. There is a strong public demand to reclaim the waters of the Clarion River and its tributaries for fishing and recreational use. Our studies indicate that with the exception of Toby Creek and other acid tributaries of the Clarion River, the river and its tributaries may be reclaimed for these uses and for water supplies after treatment without undue hardship on the polluters of the waters.

Toby Creek, the South Branch of Elk Creek and certain minor tributaries near Clarion are currently receiving acid mine drainage in sufficient concentration to render the water too acid to sustain aquatic life and bacteria. Toby Creek also receives municipal sewage from the borough of Brockway. Under Section 202 of Article II of Pamphlet Laws 1987 of 1937, the discharge of sewage into a stream already impregnated with acid coal-mine drainage is permitted when the discharge of sewage does not create a condition inimical to the public interests. Under Section 310 of Article III of Pamphlet Laws 1987 of 1937 and the amendment provided by Section 6 of Pamphlet Laws 435 of 1945, existing pollution caused by acid mine drainage from coal mines need not be abated until such time as in the opinion of the Sanitary Water Board practical means for the removal of the polluting properties of such drainage shall become known. In compliance with the law Toby Creek has been specifically excluded from our studies by the Sanitary Water Board and the standards of quality to be established will not apply to Toby Creek for the present. Our studies reveal that the Toby Creek and other acid streams in the lower valley are sufficiently diluted upon discharge into the Clarion River so that the effect of their acidity on increasing the acidity of the Clarion River water downstream from the confluences may be disregarded. The exclusion under the law therefore is limited to Toby Creek and its acid tributaries and to the acid streams near Clarion.

The South Branch of Elk Creek has been included in our studies because it receives wastes which are harmful to Elk Creek. We find that the acidity of the South Branch is insufficient to permit Elk Creek below the confluence of the two branches to be classified as an acid stream. Inasmuch as nothing may be done at present towards the elimination of the mine drainage, we propose to exclude the waters of the South Branch from compliance with the standards of acidity to be set but to require compliance of the South Branch waters with the other water quality standards.

In the light of the above discussion it is proposed to set standards of quality on the waters of the Clarion River and its tributaries, excepting Toby Creek and the acid streams in the lower valley and excepting the South Branch of Elk Creek with relation to acidity, which will permit their use for public and industrial water supply after treatment, for fish propagation, recreation and bathing, and for water power. It is proposed, furthermore, to set standards of water quality which will not destroy the reasonable use of these waters for the disposal of sewage and industrial wastes.

Legal Definition of Pollution

Section 1 of Article I of Pamphlet Laws 1987 of 1937 states that "Pollution" shall be construed to mean noxious and deleterious substances rendering unclean the waters of the Commonwealth to the extent of being *harmful*

or *inimical* to the public health or to animal or aquatic life or to the use of such waters for domestic water supply or industrial purposes or for recreation. The law further provides that the Sanitary Water Board shall determine when the discharge of any industrial wastes or the effluents therefrom constitutes pollution as therein defined and shall establish standards whereby and wherefrom, so far as reasonably practicable and possible, it can be ascertained and determined whether any such discharge does or does not constitute pollution as therein defined. It is further provided in Section 202 of Article II that the discharge of sewage causes pollution when, in the opinion of the Board, such discharge is or may become *inimical* or *injurious* to the public health, animal or aquatic life, or to the use of the water for domestic and industrial consumption or recreation.

For deleterious substances to constitute pollution the legal definition requires that they be *harmful, injurious* or *inimical.* The mere presence of small amounts of otherwise deleterious or noxious substances in the river waters is not sufficient to constitute pollution. The substances must be present in sufficient concentrations to be harmful or inimical. Thus pollution is determined by the amount of deleterious and noxious substances being discharged into the streams and the amount of water flowing in the streams. Since the flow of a stream is quite variable with the rainfall a stream receiving a given amount of deleterious materials may be polluted at low flows but not polluted at high flows. A complete abatement of pollution therefore requires that the concentration of deleterious and noxious substances be low enough during drought flows so as not to be harmful or inimical at any time. Our studies of the hydrometric data available for the Clarion River as described hereinafter indicate that the standards of water quality may be established for river and tributary flows corresponding to a run-off of 0.10 cubic feet per second per square mile of drainage area. This flow corresponds approximately to the drought flow conditions as defined jointly by the Department of Forests and Waters and the Department of Health. This flow will be exceeded on the average about 99% of the time. It is proposed to set water quality standards which are safe enough at the 1% flow condition to avoid harm at more extreme flows.

Some of the deleterious substances now causing pollution are harmful not of themselves but because of their indirect effect upon the concentration of other constituents in the water which do effect its quality. Most of the existing pollution in the Clarion River, for example, is due to the discharge of putrescible organic matter into the river. The organic matter itself is relatively harmless but it undergoes bacterial decomposition in the river waters during which the dissolved-oxygen content of the waters is reduced sufficiently to damage aquatic life and cause nuisance. It is proposed, therefore, to set the water quality standards in terms of the minimum oxygen level to be maintained rather than in terms of the concentration of organic matter to be allowed. The allowable concentration of putrescible organic matter is variable from point to point in the streams depending upon the reaeration capacity of the stream but the minimum oxygen content allowable will be the same everywhere.

STANDARDS OF RIVER WATER QUALITY

The characteristics of water quality which are of significance for the proposed uses of the Clarion River and its tributaries are: (1) the minimum allowable dissolved oxygen content, (2) the maximum concentration of

coliform bacteria, (3) the allowable range in pH value for the water, (4) the allowable concentration of toxic substances in the water, (5) the allowable range in the temperature of the water, (6) the allowable increase in color and turbidity by artificial pollution, (7) the allowable concentrations of oil and grease, (8) the allowable concentrations of suspended and floating solids in the water, (9) the allowable concentrations of materials which cause odor nuisances or taste and odor difficulties in water supplies and (10) the allowable increase in dissolved salts by artificial pollution. We recommend the adoption of water quality standards as set forth in Table 1. The arguments in support of the proposed standards are discussed below.

Dissolved Oxygen

The minimum dissolved oxygen level is determined by the requirements of fish life. If these requirements are met the dissolved oxygen level will be more than adequate for all other proposed uses of the waters of the Clarion River and its tributaries. According to Paton (See Arch E. Cole "The Effects of Pollutional Wastes on Fish Life," a Symposium on Hydrobiology, the University of Wisconsin Press, 1941), the asphyxial point for young trout is 2.9 parts per million (ppm). According to Gardner & King the oxygen threshold for trout is 1.14 ppm at 6.5° C. and 3.4 ppm at 25° C. Bergman found that perch begin to manifest respiratory difficulties at 2.0 ppm and Wilding found that the oxygen threshold for perch, the blunt nosed minnow and the steel headed minnow is 2.25 ppm at 20 to 26° C. Ellis concludes that 5.0 ppm of dissolved oxygen is the lowest level that might reasonably be expected to maintain a varied fish fauna in good condition. In the light of the above, an allowable organic pollution load which will result in an oxygen level of 4 ppm at the 1% flow will produce oxygen concentrations in excess of 4 ppm 99% of the time and should not produce asphyxial concentrations at the extreme low flows.

Coliform Bacteria

Coliform bacteria are discharged in human fecal matter at the rate of 100 to 400 billion per person per day. Their presence in water is therefore an index of sewage pollution and an indication of the possibility of the simultaneous presence of intestinal disease germs. The coliform concentration in water is an indicator of the concentration of fresh sewage and the probability of the presence of disease germs. If the water is to be used continuously for drinking purposes the coliform count of the treated water in terms of the most probable number (MPN) should not exceed 1 per 100 milliliters (ml) on the average. It is not proposed to approve the use of the Clarion River water for drinking purposes except after treatment by modern rapid sand filtration and chlorination. A raw water with a coliform count of 5,000 per 100 ml on the average may be successfully treated in such a plant to produce a finished water with less than 1 coliform bacterium per 100 ml. If the waters of the Clarion River and its tributaries are to be used for recreational purposes and bathing, occasional drinking of the water is to be expected. Inasmuch as the amount of water taken into the mouth in this manner by an individual is a very small part of the total amount of water he drinks, the safe allowable coliform content of bathing waters may be very much higher than for waters used continuously for drinking purposes

with the same probability of intestinal infection. Many public health authorities permit coliform counts up to 1,000 per 100 ml on the average for recreational and bathing waters and maximum limits of 2,500. Epidemiological evidence is lacking to indicate that these standards are not safe. We therefore recommend the adoption for the Clarion River and its tributaries of

TABLE I. PROPOSED STANDARDS OF WATER QUALITY FOR CLARION RIVER AND ITS TRIBUTARIES

1. Dissolved oxygen	Not less than 4 ppm except at extreme low flows which occur less than 1% of the time.
2. Coliform bacteria, MPN per 100 ml	Median less than 1000. Maximum less than 2500 at all stream flows.
3. pH value	Between 5.5 and 8.5 at all times.
4. Toxic substances	Absent or in concentrations well below toxic levels.
5. Temperature	Not to be increased artificially by amounts sufficient to be harmful to aquatic life.
6. Color and turbidity, except from natural sources	Not in objectionable concentrations.
7. Oil, grease and tars	No objectionable amounts.
8. Suspended and floating solids, except from natural sources	Not in amounts sufficient to be objectionable or to cause sludge banks.
9. Taste and odor producing substances except from natural sources	Not in sufficient concentration to cause odor nuisance along the streams, to impair the palatability of fish or to cause taste and odor difficulties in the water supplies which cannot be resolved by conventional treatment methods.
10. Dissolved salts, except from natural sources	Not in sufficient concentrations to injure aquatic life or to cause excessive damage to water supplies.

a median coliform concentration of less than 1,000 per 100 ml in terms of the MPN and a maximum count at any time of not more than 2,500 per 100 ml.

Acidity and Alkalinity

The waters of the Clarion River and its tributaries should be neither too acid nor too alkaline to maintain a varied fish fauna in good condition. The best measure of the acidity or alkalinity is the hydrogen-ion concentration which is commonly expressed in terms of the pH value of the water. The pH value should be suitable not only for the fish but also for the aquatic life utilized as food by the fish. The ability of fishes to utilize oxygen at low concentration varies with the pH value of the water and is favored by a high alkaline reserve in the blood. Thus alkaline waters are more favorable to the maintenance of fish life at low oxygen levels than acid waters. According to Schaperclaus (See paper by Cole previously referred to), the lower pH limit for fresh water fishes is 4.8 and the upper limit is 8.0. Other authorities, however, report a range from a low of 4.4 to a high of 8.7. In our judgment a pH range from 5.5 to 8.5 is safe for aquatic life and

we recommend its adoption for the waters of the Clarion River and its tributaries.

Other Characteristics

No numerical standards are recommended for the last seven water quality characteristics proposed in Table 1. Our studies indicate that these characteristics are not now of major importance in affecting the quality of the waters. There are isolated and specific instances of excesses on some of them. It is proposed to study each excess on its merits and to adopt a suitable standard to conform.

Our studies did not reveal the presence of any toxic substances or substances which in combination with others produce toxic substances in the waters of the Clarion River and its tributaries. Use of the waters for cooling and other industrial purposes results in increased temperatures. Our studies reveal however that the water temperature is occasionally increased by natural causes to more than 30° C. It is proposed to set no numerical limit on the allowable increase in temperature by artificial means until it is found that existing uses of the water result in temperature increases which are harmful to aquatic life. Our studies reveal the existence of objectionable increases in color and turbidity from the discharge of industrial wastes. Much of the objectionable color and turbidity will be removed by the treatment required for the abatement of other pollutants. Specific recommendations will be made hereinafter for isolated cases where color is the major problem. Specific recommendations will also be made for isolated cases involving the discharge of oils and tars in objectionable amounts.

Our studies reveal the presence of suspended and floating solids in great quantities sufficient to cause sludge banks in many stretches of the river and its tributaries. Most of this material is organic matter and will be removed from the river by the treatment processes which are required to sustain satisfactory oxygen levels and to reduce bacterial pollution. Specific recommendations will be made for isolated cases involving the discharge of inert solids. Our studies reveal that taste and odor producing substances are associated with the organic matter being discharged from some of the industries. It is expected that these substances will be very largely removed from the waters by the treatment processes and other improvements required to sustain satisfactory oxygen levels. It is proposed to set no numerical standards for taste and odor producing substances until it is found that they persist even after the removal of pollutants principally responsible for low oxygen levels.

Our studies reveal that dissolved salts are currently being discharged into the Clarion River and its tributaries with the wastes from industries. Most of these salts are alkalis and some of them increase the hardness of the stream waters. There is no evidence that the concentration of dissolved salts is high enough to have any significant effect on aquatic life, but the increase in hardness does affect the water users downstream. Some of the water users have well supplies the hardness of which is much in excess of any values observed on the Clarion River waters. Thus, the current discharge in industrial wastes of salts contributing to the hardness of the water is not of sufficient economic significance to justify cognizance of it by the Sanitary Water Board. It is recommended that this phase of pollution be watched and that the polluters be cautioned lest the increase in hardness gets sufficiently out of line to require action by the Sanitary Water Board.

CHAPTER III.

INVESTIGATIONS TO DETERMINE THE EXTENT OF POLLUTION IN RIVER WATERS

Approach to the Problem

It has been stated hereinbefore that the results of previous surveys of the Clarion River are inadequate in scope to determine the extent of pollution and the amount of abatement required. All the previous surveys show gross pollution, but they do not furnish the factors which are required in order to estimate the power of streams to assimilate pollutants.

The most important pollutant in the case of the Clarion River basin is putrescible organic matter. The principal harmful effect of organic matter is felt indirectly through depletion of the dissolved-oxygen content of the waters when the organic matter is used by bacteria for food. Bacterial feeding is a biochemical process and requires considerable time. It is necessary therefore to measure the rates at which oxygen is used up in the stream and the time of flow between points of pollution. During the time of flow of the stream, the waters will recover oxygen by solution from the atmosphere. For a reliable evaluation it is also necessary to estimate the rates at which oxygen will be obtained from the atmosphere by reaeration. The study of the rates of deoxygenation and reaeration, commonly termed the "oxygen balance," depends on both laboratory analyses and hydrometric data on the streams.

Our method of approach to the pollution abatement problem in the Clarion River basin has therefore been based primarily upon a determination of the assimilating capacity of the waters by means of the oxygen balance. The assimilating capacity for other pollutants than organic matter has also been determined.

LABORATORY TECHNIQUES AND THEORY

A thorough study was made of all available chemical and bacterial analyses of the waters of the Clarion River and its tributaries, supplemented where necessary by more detailed tests conducted in a temporary field laboratory established for this purpose at Ridgway, Pennsylvania. From previous analyses and from our own tests, we have determined the concentrations of substances which are apt to be harmful or inimical, especially putrescible organic matter as measured by the biochemical oxygen demand (BOD). Supplementary to the test for BOD, we have also determined the effect of such organic pollutants by measurement of the dissolved-oxygen content at many points along the main river and its tributaries. These data have been subjected to extensive computations to determine the ability of the streams to absorb deleterious substances without causing pollution as defined in terms of the water quality standards described hereinbefore.

The chemical and biochemical analyses conducted by our personnel were performed as recommended in the ninth edition of "Standard Methods for the Examination of Water and Sewage," published by the American Public

Health Association, 1946. The alkaline-hypochlorite modification of the dissolved-oxygen test was used whenever we had determined or suspected the presence of sulfites or related reducing substances. Otherwise the sodium-azide modification of the Winkler method was used. An electrometric pH meter was used for the determination of pH, acidity, and alkalinity. Acidity and alkalinity were measured to pH 8.2 and pH 4.3, corresponding roughly to the phenolphthalein and methyl-orange end points. Total solids, suspended solids, sulfides, calcium, chlorides, and other routine tests were conducted in the conventional manner as prescribed by Standard Methods.

Determination of Reaction Rates

The BOD test was conducted with the new standard fortified dilution water as described in Standard Methods. We considered the possible use of natural unpolluted river water for this purpose but found its quality to be too variable, depending upon rainfall and run-off rates. It was deemed advisable to obtain all of our results with a known standard dilution water so that they might be compared with results of previous studies and with subsequent tests. On all river samples, complete BOD curves were determined, i.e. the BOD after 1, 2, 3, 4, 5, 6, 7, and 10 days (and occasionally after 15 or 20 days). A typical complete curve is shown by Fig. 2. It is generally recognized that the rate at which oxygen is used is proportional to the concentration of remaining organic matter, or

$$\frac{dy}{dt} = K_1 (L - y) \tag{1}$$

In the integrated form this becomes

$$y = L (1 - e^{-K_1 t}) \tag{2}$$

or

$$y = L (1 - 10^{-k_1 t}) \tag{3}$$

where $k_1 = 0.434\ K_1$. To determine the reaction rate, k_1, and the ultimate first-stage BOD value, L, it was necessary to secure data for the entire curve and to make a statistical fit by the method of moments. As will be shown hereinafter, a knowledge of these rate constants is essential for the determination of the assimilative capacity of a stream.

Sulfites and Related Compounds

As a measure of the sulfites and related reducing compounds found in the Clarion River below Johnsonburg we employed the test described in Standard Methods based on the reduction of iodine. It is realized that this test is not specific for sulfites, since it also measures polythionates, sulfides, nitrites, and other reducing compounds. For that reason, we have designated our results as "equivalent sulfites." In this particular study, the test was useful to determine when the alkaline-hypochlorite modification of the dissolved-oxygen test should be used, and also to measure the persistence of sulfites and related compounds as the river recovered in flowing downstream from Johnsonburg.

Oxygen Balance

The concentration of most chemical substances in a stream is related almost directly to the available dilution. Consequently, it is possible to predict from a measured concentration of a given substance at a known stream flow what concentration would obtain at other stream flows and also what would be the effect of varying degrees of treatment. Such a simple relationship does not apply, however, to the effects of putrescible organic matter on the dissolved-oxygen content of a stream. The capacity of a stream to receive and assimilate organic municipal and industrial wastes without harmful or inimical effects upon the dissolved-oxygen content depends not only upon the BOD of the wastes and the dilution in the stream, but also upon the rate at which such wastes cause deoxygenation in the stream by bacterial decomposition and the rate at which the stream is reaerated from the atmosphere. The effects of organic matter in a stream are also dependent upon sedimentation, chemical oxidation, biological slimes, decomposition of benthal deposits and temperature. A balance of the various factors of deoxygenation and reaeration generally produces a decrease in the dissolved-oxygen content downstream from a point of pollution, followed by a gradual recovery. This sag in the dissolved-oxygen content is seldom harmful if it does not reduce the residual oxygen content of the stream below 4.0 ppm, as required for the survival and propagation of game fish.

The concepts of oxygen balance in a river have been formulated and developed by many writers, foremost among whom have been Streeter and Phelps. More recently, the use of the theory has been improved somewhat by Thomas (Water and Sewage Works, November, 1948). We shall not attempt to review in this report the entire theory of oxygen balance, but in order to explain our determinations of the assimilative capacities of the stream, the following summary of the basic concepts as applied to these investigations is presented.

Oxygen Sag Curve

The general effect of organic pollution upon the dissolved-oxygen content of a stream is shown diagrammatically in Figure 3. Prior to the introduction of polluting organic matter, the dissolved-oxygen content is at or near saturation, but after pollution the oxygen content drops. The difference between the saturation value and the actual oxygen content is known as the oxygen deficit, D. The entire oxygen-sag curve has been formulated as follows:

$$\frac{dD}{dt} = 2.3\ (k_d L - k_2 D) \qquad (4)$$

where $\frac{dD}{dt}$ is the rate of change of the deficit, D

$k_d L$ is the rate of oxygen utilization

$k_2 D$ is the rate of reaeration

The rate of oxygen utilization is proportional to the amount of oxidizable organic matter as measured by the ultimate first-stage BOD, L. The proportionality constant of deoxygenation is expressed as k_d. In the

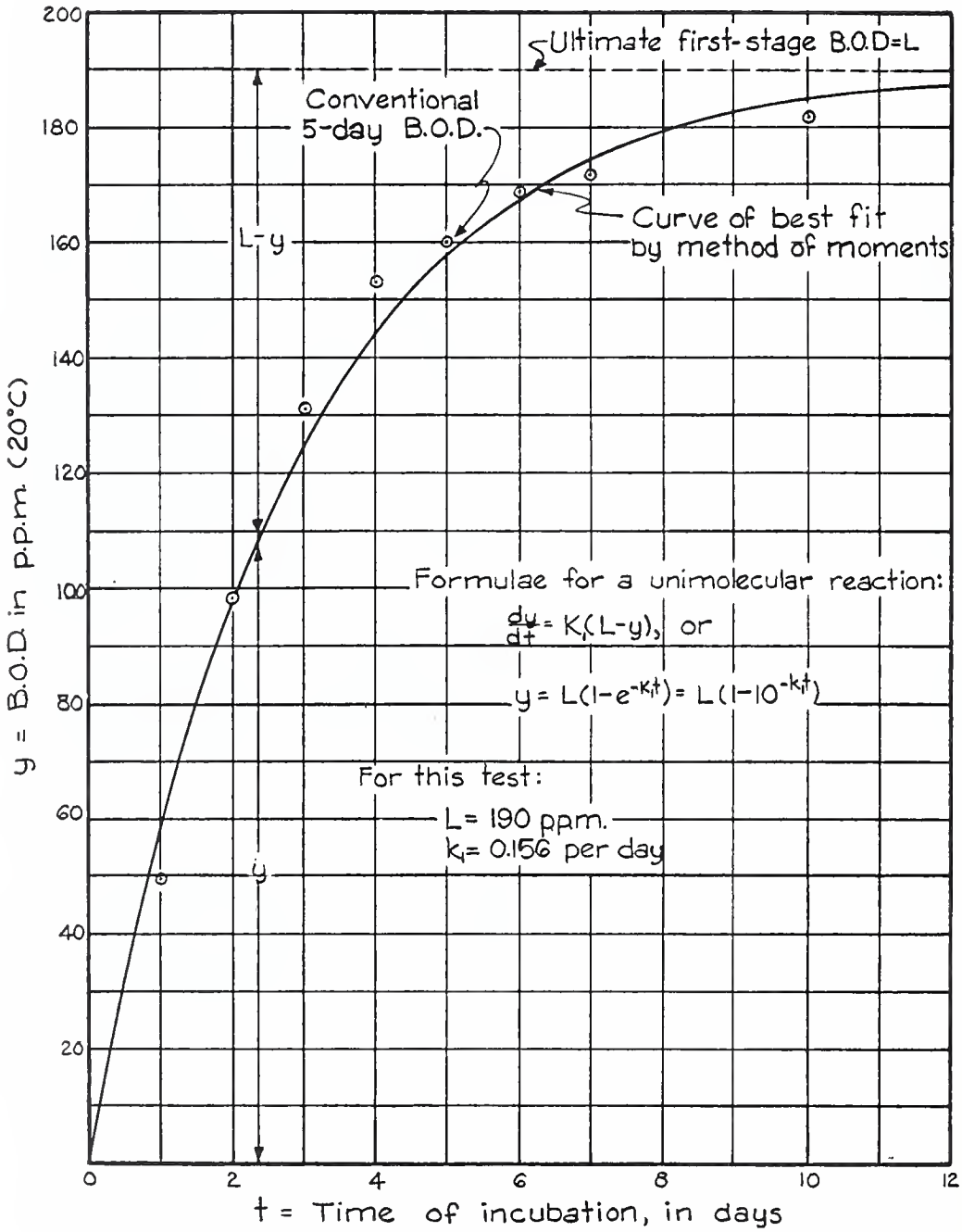

FIGURE 2.

TYPICAL COMPLETE FIRST-STAGE BOD CURVE
(Clarion River below mouth of Riley Run)

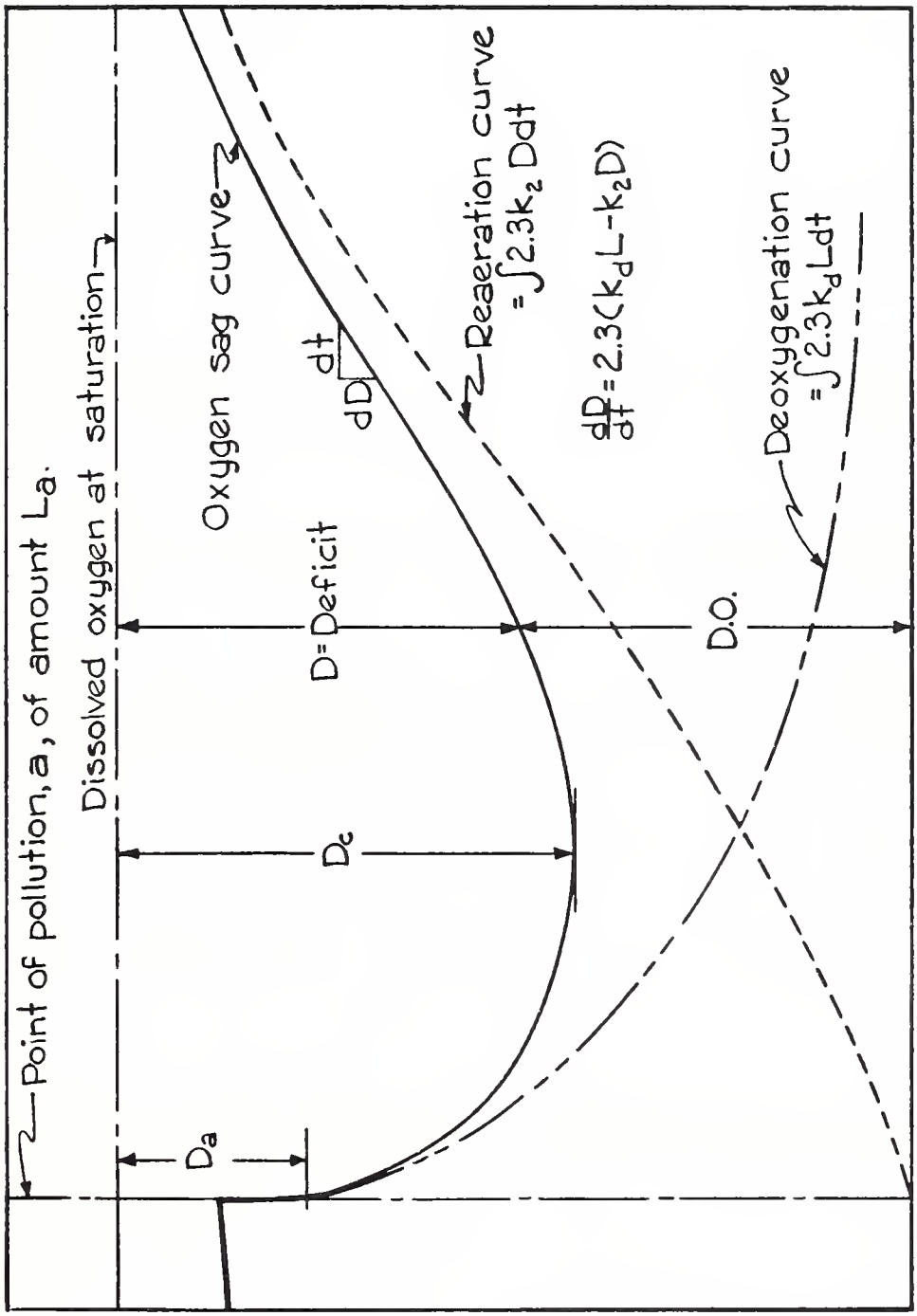

FIGURE 3.

DIAGRAM OF A TYPICAL OXYGEN SAG CURVE

BOD test itself, $k_d = k_1$. In a river, however, k_d may be somewhat greater than k_1 where deoxygenation is accelerated by aerobic slime growths on rock surfaces, or it may be less than k_1 if the river water is not as well balanced nutritively as the synthetic dilution water used in the BOD test. Inasmuch as no means have been developed for the measurement of k_d, it has generally been assumed by past investigators to be equal to k_1. We have found, however, that the rate of oxygen utilization is more closely related to the rate of BOD removal by the stream, or k_d is about equal to k_r, as explained below.

Below the point of pollution the amount of oxidizable organic matter in the stream is decreased by biochemical action, sedimentation and other factors. This decrease generally proceeds in a unimolecular fashion so that the rate of change of L is proportional to the amount remaining, or

$$\frac{dL}{dt} = 2.3\ k_r L \tag{5}$$

where k_r is the proportionality constant of BOD removal for the particular stretch of river. In the integrated form, this equation becomes:

$$L_b = L_a \cdot 10^{-k_r t} \tag{6}$$

where L_a is the initial BOD load and L_b is the load after time, t. The value of k_r can be measured in a stream by determining t, L_a and L_b. Then

$$k_r = \frac{1}{t} \log \frac{L_a}{L_b} \tag{7}$$

Experience has shown that the proportionality constant k_r in a stream is seldom equal to the deoxygenation constant, k_1 determined from incubated bottles in the BOD test because of the effects of sedimentation, slime growths, benthal deposits, escape of volatile substances, etc. Thomas has grouped all of these effects in another constant, k_3, such that $k_r = k_1 + k_3$. When BOD is removed by sedimentation, volatilization or biological slimes, k_3 is positive and may even be greater than k_1. When BOD is returned to the flowing waters by bottom scour, by the exuding of dissolved organic matter from previously deposited sludge, or by rising masses from sludge banks, k_3 may be negative. Since k_r and k_1 are readily found for any reach of a stream by sampling and analysis, k_3 can be determined by subtraction. See Example No. 1.

EXAMPLE No. 1

West Branch from one mile below Wilcox to concrete bridge at Rolfe (see Table 8).

Q_a = 4.85 mgd. L_a = 14.5 ppm x 4.85 x 8.33 = 587 lbs per day @ 20°C.

From page 31, L_a at 10.1°C = 587 [1 + 0.02 (10.1-20)] = 470 lbs per day.

Q_b = 6.69 mgd. L_b = 4.05 x 6.69 x 8.33 = 226 lbs per day @ 20°C.

From page 31, L_b at 10.0°C = 226 [1 + 0.02 (10.0-20)] = 181 lbs per day.

From Table 2, D.A. for Sta. a is 68 sq. miles

$$Q_a = \frac{4.85 \times 1.547}{68} = 0.11 \text{ cfs per sq. mi.}$$

$V_a = V_b$ = from Fig. 6 = 0.544 mph

From Table 2, Distance Station a to Sta. b = 103.3 − 98.9 = 4.4 miles

Time of flow, $t = \frac{4.4}{0.544} \times \frac{1}{24} = 0.337$ days

From Eq. (7), page 28,

$$k_r = \frac{1}{t} \log \frac{L_a}{L_b} = \frac{1}{0.337} \times \log \frac{470}{181} = 1.24 \text{ @ } 10° \text{ C}$$

From Table 8:
At Sta a, $k_1 = 0.053$ @ 20°C
At Sta b, $k_1 = 0.0965$ @ 20°C Ave. $k_1 = 0.075$ @ 20°C (see Table 11)

From page 31:
At Sta. a, k_1 @ 10.1°C = $0.053\ (1.047)^{10.1-20} = 0.0335$
At Sta. b, k_1 @ 10°C = $0.0965\ (1.047)^{10-20} = 0.0611$
Ave. k_1 @ Stations a and b @ 10°C = about 0.05

From page 28
For Reach, Sta. a to b, $k_3 = k_r - k_1 = 1.24 - 0.05 = 1.19$ @ 10°C

From page 31:

For Reach-k_3 @ 20°C = $\frac{1.19}{(1.047)^{10.1-20}} = 1.88$ (see Table 11)

The use of the proportionality constant k_d has been limited to reaches where conditions have been found to be aerobic and where anaerobic sludge deposits are of secondary importance. In all such cases it has been assumed that the rate of utilization of oxygen is equal to the rate of BOD removal, or that k_d is equal to k_r.

The rate of atmospheric reaeration is proportional to the oxygen deficit, D, with the proportionality constant being conventionally expressed as k_2. The value of k_2 is influenced by the ratio of exposed surface area to volume, by turbulence and the velocity of flow, and by temperature. It is much greater in rapids than in pools; in turbulent mountain streams than in sluggish rivers. The value of k_2 might be determined experimentally in a laboratory for a standard set of conditions, but the results so obtained are difficult to apply to a natural stream consisting of varying lengths of pools and rapids. The k_2 value can be obtained for any short stretch of stream, however, by calculation from the differential form of the oxygen-sag formula, thus:

$$k_2 = \frac{1}{D}\left(k_d L - 0.434 \frac{\Delta D}{\Delta t}\right) \quad (8)$$

or for long reaches from the integrated formula:

$$D_b = \frac{k_d L_a}{k_2 - k_r}\left(10^{-k_r t} - 10^{-k_2 t}\right) + D_a \cdot 10^{-k_2 t} \quad (9)$$

assuming in both of the above formulae that $k_d = k_r$. See Example No. 2.

EXAMPLE No. 2

West Branch from one mile below Wilcox to concrete bridge at Rolfe (see Example 1).

From Table 8, D.O. at a = 9.87 ppm

D.O. at saturation = 11.33 ppm at 10.1°C.

$D_a = (11.33 - 9.87) \times 4.85$ mgd $\times 8.33 = 59.0$ lbs per day.

Similarly, $D_b = (11.33 - 10.40) \times 6.69 \times 8.33 = 51.8$ lbs per day.

$$\text{Average } D = \frac{59.0 + 51.8}{2} = 55.4$$

$\Delta D = 51.8 - 59 = -7.2$ lbs per day

$\Delta t = t = 0.337$ days

$$\text{Average } L = \frac{470 + 181}{2} = 325.5 \text{ lbs per day at } 10°C.$$

Then from Eq. (8), page 30

$$k_2 = \frac{1}{D}\left(k_r L - 0.434 \frac{D}{t}\right)$$

$$= \frac{1}{55.4}\left(1.24 \times 325.5 - 0.434 \frac{-7.2}{0.337}\right)$$

$$= 7.45 \text{ at } 10°C$$

From page 31,

$$k_2 \text{ at } 20°C. = \frac{7.45}{(1.0159)^{10\text{-}20}} = 8.74 \text{ (see Table 11)}$$

It is realized that the value of k_2 is not constant in any stretch of a stream, but changes as the stream flow increases or decreases. For that reason, we have attempted to evaluate k_2 at minimum stream flows corresponding approximately to the conditions that will obtain in the river at critical periods.

Inasmuch as the temperature of the river waters varies from day to day,

all factors in the oxygen-balance relationship must be corrected to a common temperature, T. The following correction factors have been used:

$$L\ @\ T^\circ = L\ @\ 20^\circ \cdot [1 + .02\ (T\text{-}20)]$$

$$k_1\ @\ T^\circ = k_1\ @\ 20^\circ \cdot (1.047)^{T\text{-}20}$$

$$k_2\ @\ T^\circ = k_2\ @\ 20^\circ \cdot (1.0159)^{T\text{-}20}$$

$$k_3\ @\ T^\circ = k_3\ @\ 20^\circ \cdot \ominus^{T\text{-}20}$$

where $\ominus$ = 1.047 for aerobic action and 1.074 for anaerobic action.

In order that we might calculate, or otherwise estimate, the effect of varying degrees of treatment upon the oxygen balance of the Clarion River, West Branch and Elk Creek, we set about to determine from our own analyses and from data previously obtained by others, the values of k_1, k_2 and k_3 in each reach of each critical stream. It was also necessary to determine the times of flow, t, at various discharges. The results of these determinations are presented below.

HYDROMETRIC DATA

Slopes of Streams and Drainage Areas

The Clarion River basin is shown on the general map, Fig. 1, and Table 2 shows the drainage area and miles above the river mouth of the principal points in the valley. Profiles of the Clarion River, Elk Creek, and West Branch are shown in Fig. 4. It is significant to note that between Johnsonburg and the mouth of the Clarion River the slope is relatively uniform, except where the stream has been impounded by Piney Dam. It is also to be noted that the slopes of Elk Creek and West Branch are much steeper than that of the Clarion River proper, and consequently it is to be expected that the velocities in these tributaries and the rates of reaeration will be much greater than in the main river.

The average rainfall in the Clarion River basin varies between 40 and 45 inches per year. Most of the area is between 1,000 and 2,000 feet above sea level. North and east of Clarion it is heavily forested with second growth scrub timber, while to the south and west of Clarion, high, rolling, agricultural lands predominate. In recent years strip mining has claimed much of the land near Clarion and some areas near Rasselas, northeast of Johnsonburg.

Storage Reservoirs

Piney Dam, completed about 1924, impounds approximately 28,800 acre feet of water at a full pond elevation of 1,093 feet, of which 13,000 acre feet are usable. Dead storage level is at elevation 1,073. At full pond, water is backed up to about one mile above Mill Creek. There are three turbines at Piney Dam which discharge about 1,400 cubic feet per second (cfs) each. No more than two turbines are ever used simultaneously. During periods of low flow in the stream, the turbines are only operated at hours of maximum demand and seldom on Sundays. When they are not operating, about 35 cfs is discharged as lubricating water and leakage. Consequently, the stream flow in the lower reaches of the Clarion River is very irregular.

TABLE 2. STREAM SAMPLING STATIONS

Map Designation	*Pennsylvania Dept. of Health Number*	*Stream*	*Description of Sampling Point*	*Miles Above Mouth of Clarion River*	*Drainage Area in Square Miles*
A	1-A	West Branch	Penna. R.R. Bridge, Wilcox	104.5	64
B	—	" "	L. bank, ¼ mile below Oil Creek	103.3	68
C	1	" "	Concrete bridge at Rolfe	98.9	94
D	2	East Branch	First Ave. bridge, Johnsonburg	98.4	110
E	—	Clarion River	Grant St. bridge, Johnsonburg	98.1	205
F	—	" "	L. bank, ¾ mile below Grant St.	97.3	218
G	3	" "	L. bank, just above Riley Run	93.6	227
H	—	" "	Ridgway Elec. Co. dam	91.5	241
I	4-A	Elk Creek	Bridge about 1 mile below St. Marys	99.6	12
J	—	" "	Bridge near Mohan Run	94.1	51
K	4	" "	Foot bridge near mouth of Elk Creek	90.2	61
L	—	Clarion River	R. bank about 1 mile below Ridgway Bridge	89.3	311
M	5	" "	L. bank, just above Toby Creek	82.5	362
N	7-a	" "	Bridge at Arroyo	76.8	523
O	7-A	" "	Bridge at Millstone	63.2	667
P	—	" "	Bridge at Clarington	57.2	744
Q	7-B	" "	Bridge at Cooksburg	48.1	794
R	8	Piney Reservoir	Bridge at Mill Creek	36.5	898
S	9	" "	Route 966 bridge at Clarion	31.5	907
T	—	" "	Outlet from Piney Dam	24.9	953
U	—	Clarion River	Bridge at Piney	23.0	954
V	10	" "	Bridge at Callensburg	16.0	1148
W	—	" "	Bridge near St. Petersburg	4.5	1235

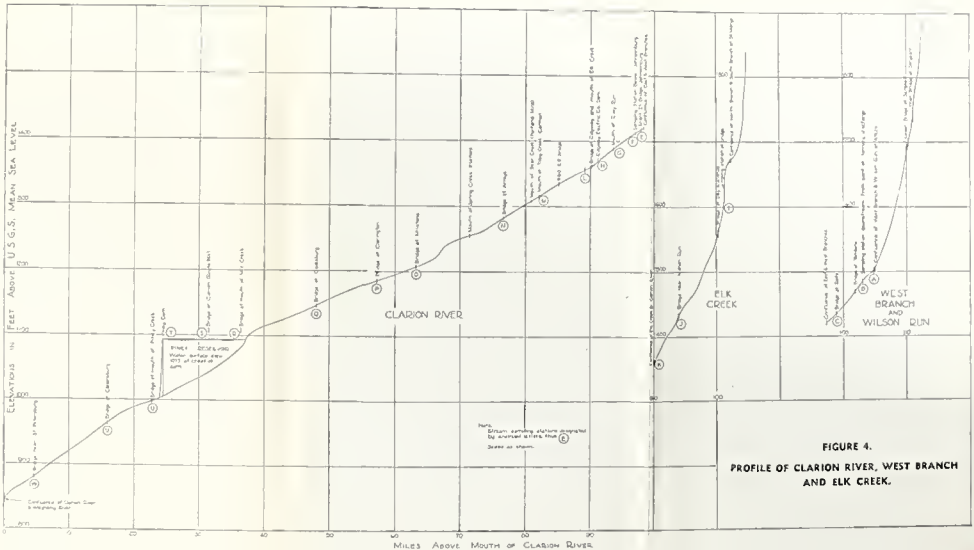
ELEVATIONS IN FEET ABOVE U.S.G.S. MEAN SEA LEVEL
MILES ABOVE MOUTH OF CLARION RIVER
CLARION RIVER
ELK CREEK
WEST BRANCH AND WILSON RUN
Note:
Bottom contour figure designated by numeral within thus (6) shown as shown.

FIGURE 4.

PROFILE OF CLARION RIVER, WEST BRANCH AND ELK CREEK.

According to present indications, the East Branch Dam will probably be completed between 1953 and 1955. It will impound approximately 84,300 acre ft of water, of which capacity from 53% to 76% will be used for low-flow regulation and the remainder for flood control. According to information released to us by the U. S. Engineer Department, the East Branch Dam would have increased the minimum flow of record at Johnsonburg from 15 cfs to 87 cfs, an increase of 72 cfs. In general, it is understood that the dam will be operated to maintain a flow of 220 cfs in the summer months at Johnsonburg; but during extreme droughts we estimate that flows as low as 87 to 92 cfs will occur at Johnsonburg, possibly in July or August when water temperatures are 25° C or higher.

The U. S. Engineer Department is still giving consideration to the construction of a reservoir on the lower Clarion River near Mill Creek, approximately at the site of the Pittsburgh Flood Commission's projected reservoir No. 3. The reservoir is being considered on two bases, for flood control only and as a multiple-purpose reservoir. On the latter basis, the reservoir would have a maximum flow line, after a flood, at elevation 1,330 and would back up flood waters about three miles above the mouth of Toby Creek. The maximum summer pool for power and low-flow regulation would be at elevation 1,316 and would extend to the mouth of Toby Creek.

Flow Duration Studies

The rate of discharge of the Clarion River has been studied on the basis of records at the following stream-gaging stations:

1. Johnsonburg. The U. S. Geological Survey maintains a chain gage on the Grant Street Bridge in Johnsonburg and obtains readings daily. The data for this station are not published but the rating curve has been established. The minimum flow of record (circa 1930) is 15 cfs, or about 0.073 cfs per sq mile.
2. Ridgway. The U. S. G. S. has maintained a chain gage at the concrete bridge in Ridgway since October, 1940. In October, 1948, it was replaced by a continuous recording gage. The drainage area at this point is reported by the U. S. G. S. to be 303 sq miles. The minimum flow of record, on September 13, 1943, was 15 cfs, or about 0.05 cfs per sq mile.
3. Cooksburg. A continuous recording gage has been maintained at the highway bridge in Cooksburg since November, 1938. The drainage area at this point is approximately 897 sq miles as reported by the U.S.G.S. and the minimum flow of record, on August 30, 1939, was 41 cfs or about 0.05 cfs per sq mile.
4. Piney Dam. At the hydro-electric plant of the Pennsylvania Electric Company at Piney Dam, the total daily discharge is computed from the records of turbine operation with an allowance for leakage. Records have been maintained since 1924.
5. St. Petersburg. The U. S. G. S. has maintained a continuous recording gage at the bridge near St. Petersburg, 4.5 miles above the mouth of the river, since 1941. The drainage area at this point is reported by the U. S. G. S. to be 1,246 sq miles. The minimum flow of record (September 26, 1943 and September 25, 1944) was 46 cfs, or about

0.037 cfs per sq mile. This stream flow record is greatly influenced by the operation of Piney Dam.

In order to establish the maximum allowable loading of a stream, just short of that which will cause pollution, it was necessary to establish minimum stream flows available for dilution. In the Commonwealth of Pennsylvania, the Department of Forests and Waters and the Department of Health have jointly established the following definitions:

Ordinary Flow, equal to the average of the remaining flows after rejecting the 90 lowest and the 90 highest flows of an approximately normal year (Normal years are taken to be 1930 and 1931).

Ordinary Low Flow, equal to the average of the 90 lowest flows, with unusual minimum flows being rejected.

Drought Flow, equal to the average of the lowest flows continuing for one week and to be expected to occur once in five years.

Inasmuch as none of the U. S. G. S. records on the Clarion River date back prior to 1939, with the exception of that at Piney Dam which was computed from operating records of the turbines and is therefore not representative of the natural stream flow, we have made a probability study of all of the stream-flow records from 1939 to 1947. The results of this study are presented in Fig. 5, with flow being generalized as cfs per sq mile. The records at Piney Dam and St. Petersburg were influenced by regulation, but the records at Ridgway and Cooksburg show close agreement when converted to the common denominator of cfs per sq mile. *Ordinary flow,* as defined above, is somewhat in excess of the 50% flow, if the data are geometrically normal. The straightness of the plot through the middle of the graph on Fig. 5 indicates this normality to be so.

Since *ordinary low flow* as defined above is the average of the 90 lowest flows, we may say approximately that 45 flows will be lower than this value and 45 of the 90 higher, or for the full year 45 out of 365 days will have flows less than the ordinary low flow. On the probability plot this corresponds approximately to the 12.3% flow or 0.25 cfs per sq mile. *Drought flow* is defined in terms of low flows continuing for one week, approximately once in five years. However, flows as low as this may occur almost every year for one or two days so that during the five-year period the total number of drought-flow days may be not seven, but twice or three times as many. Fourteen such days in five years corresponds to the 0.7% flow and twenty-one such days to the 1.05% flow. Drought flow, therefore, is approximately equal to the 1% flow, or 0.10 cfs per sq mile. In the studies which are described hereinafter we have adopted drought flow or 0.1 cfs per sq mile as the flow at which the minimum water quality standards shall apply. Drought flow at Johnsonburg is approximately equal to 20.5 cfs. The lowest flow of record at Johnsonburg, 15 cfs, may be expected approximately 0.1% of the time, or about one day every three years. We do not feel that flows less than 0.1 cfs per sq mile are sufficiently numerous to justify the added cost of pollution abatement required thereby.

Velocity of Stream Flow

Equal in importance with the deoxygenation and reaeration constants in the oxygen-sag formulation is the time of flow, t, between sampling stations. The time of flow is extremely difficult of determination. Until it is measured

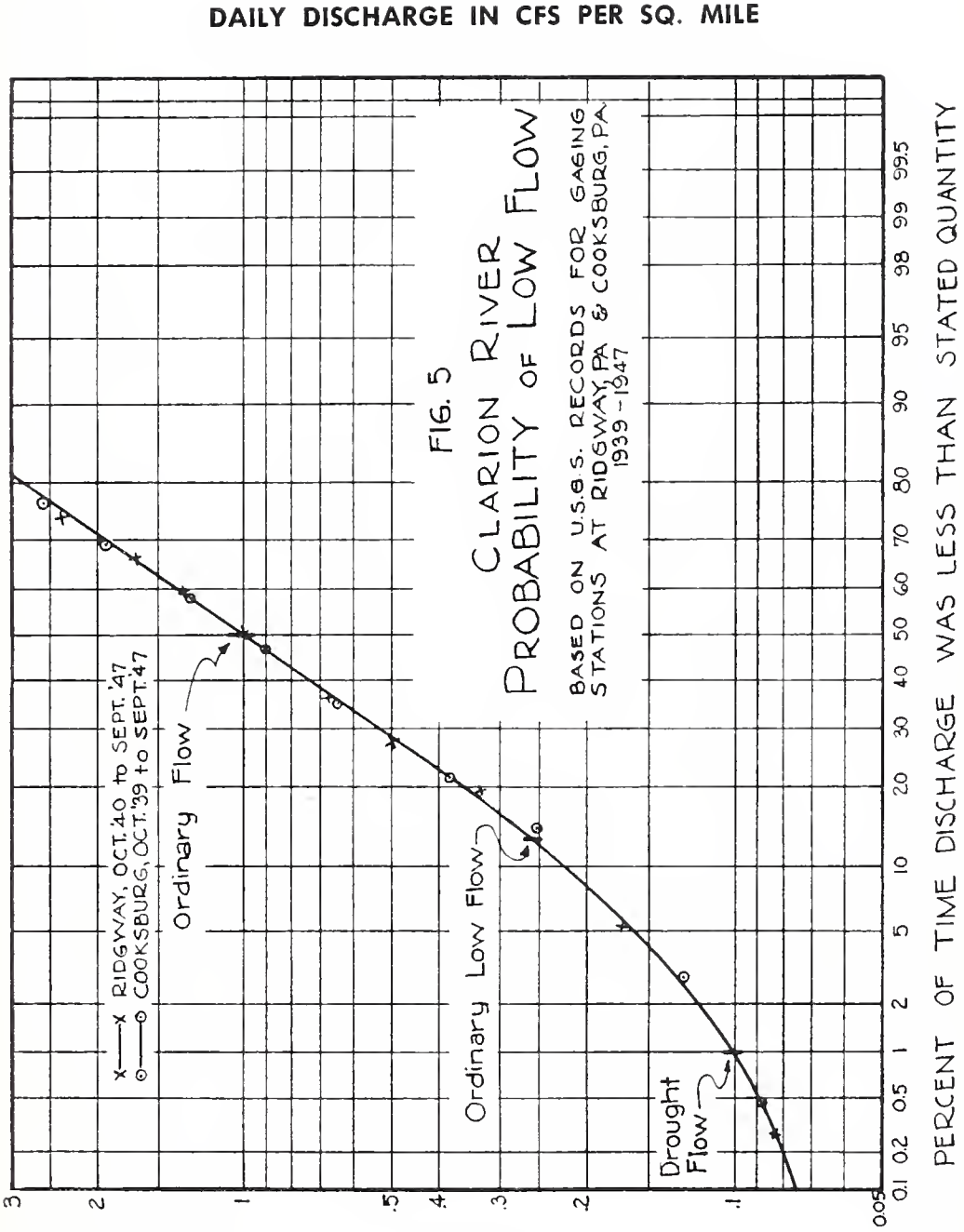
DAILY DISCHARGE IN CFS PER SQ. MILE
FIG. 5
CLARION RIVER
PROBABILITY OF LOW FLOW
BASED ON U.S.G.S. RECORDS FOR GAGING STATIONS AT RIDGWAY, PA & COOKSBURG, PA. 1939 - 1947
RIDGWAY, OCT. 40 to SEPT. '47
COOKSBURG, OCT. '39 to SEPT. 47
Ordinary Flow
Ordinary Low Flow
Drought Flow
3
2
1
.5
.4
.3
.2
.1
.05
0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.5
PERCENT OF TIME DISCHARGE WAS LESS THAN STATED QUANTITY

FIGURE 5.

with a fair degree of accuracy, values of k_r, k_2, and k_3 cannot be computed reliably. In order to determine the time of flow, t, we considered the conventional tests with dye and salt but found them to be impracticable on the Clarion River because of the magnitude of flows involved and the masking effect of pollution in the river. We also considered timing the passage of wave crests or troughs between the stream-gaging stations, but inasmuch as the only two recording gages are at Cooksburg and St. Petersburg, separated by Piney Reservoir, such an approach was impracticable. Consideration was also given to timing the passage of slugs of industrial wastes, but no well-defined slugs were discernible which could be followed downstream. The use of radioactive substances to measure velocity presented a possible approach, but this means was ruled out because the techniques and controls of the method are not yet developed fully. In any future velocity studies, we recommend that the use of radioactive tracers be given serious consideration.

The only practical method of measuring velocity in the streams being studied was by timing the passage of wood chips or oranges through many short stretches of pools and rapids. Preliminary experiments were made on Elk Creek at St. Marys to compare the velocities of uranine dye and chips. These tests showed that the chips move as fast as the first trace of dye and that the deepest intensity (the modal time of flow) had a velocity approximately 80% of that of the chips. We have therefore considered the average time of flow of the water in the stream in each reach to be 25% greater than the observed time of passage of chips.

At low river stages the Clarion River and its tributaries consist of many series of shallow pools interspersed with stretches of rapids or riffles. The pools may be compared to sedimentation basins with overflow weirs, and hence the velocity through such pools varies almost directly with the discharge. The velocities in rapids and riffles depend upon the slope and roughness of the stretch as well as upon the discharge. We have noted the location of rapids and pools over most of the river between Johnsonburg and Cooksburg and these surveys indicate that at low stages the river consists of about 67% pools and 33% rapids. On this basis, with average velocities V_p and V_r respectively for the pools and rapids, the average velocity $\overline{V}$ for a reach is

$$\overline{V} = \frac{3V_p \times V_r}{V_p + 2V_r} \tag{10}$$

This formula indicates that the velocities in the pools have much more effect upon the average velocity than do the velocities in the rapids.

In 1940, the U. S. Engineers conducted chip velocity tests similar to ours but at higher river stages. Their data have been made available to us and we have used them in conjunction with our studies. In general it was found that velocities in the pools between Johnsonburg and Carman (near the mouth of Toby Creek) were somewhat slower than in the reach between Carman and Cooksburg. For that reason we have divided the river into these two general reaches. The results of our velocity studies and the U. S. Engineers' data are presented in Tables 3 and 4, and plotted on Fig. 6.

Similar studies were made of velocities in Elk Creek between St. Marys and Ridgway and the West Branch of the Clarion River below Wilcox. These results are also plotted in Fig. 6. It is to be noted that velocities

TABLE 3. VELOCITY STUDIES, JOHNSONBURG TO CARMAN

Date: 1948	*Aug 17*	*Sept 15*	*Sept 28*
Discharge in cfs per sq mi, Ridgway & Cooksburg gaging stations	0.36	0.14	0.12
Pools:	*Chip velocities in feet per second*		
Opposite sulfite lagoons	.46	.38	.28
At Riley's Run	.75	.17	.33
Behind Ridgway Elec. Co. Dam	.21	.12	.26
Above Toby Creek	.36	.56	.28
Average velocity in rapids, V_p	.45	.31	.29
Rapids and Riffles:			
Johnsonburg Bridge	.90	.92	.67
1 mile below Johnsonburg Bridge	1.33	1.33	1.29
Above Riley's Run	1.00	1.04	1.20
Ridgway Bridge	.84	.48	—
River Mile 86+	.94	.70	1.00
B. & O. R.R. Bridge	2.00	1.09	1.20
Average velocity in rapids, V_r	1.17	.93	1.07
$\overline{V} = \frac{3V_p \times V_r}{V_p + 2V_r}$ $\overline{V}$ in fps =	0.565	0.398	0.383
$\overline{V}$ in mph =	0.384	0.272	0.261
Figures based on U. S. Engineers data:			
Discharge in cfs per sq mi at Cooksburg	0.51	1.01	1.51
	Chip velocities in miles per hour		
Reach E, near Carman	0.47	0.82	1.12
Reach F, near Riley's Run	0.72	1.10	1.40
Average	0.60	0.96	1.26

Note: Average stream velocities are taken as 80% of above chip velocities

TABLE 4. VELOCITY STUDIES, CARMAN TO COOKSBURG

Date: 1948	*Aug 17*	*Sept 17*	*Sept 28*
Discharge in cfs per sq mi at Cooksburg	0.35	0.13	0.12
Pools:	*Chip velocities in feet per second*		
River Mile 68+	0.78	0.50	0.44
Clarington Bridge	0.81	0.33	0.34
Cooksburg Bridge	0.80	—	—
Millstone Bridge	—	0.36	—
Average velocity in pools, V_p	0.80	0.40	0.39
Rapids and Riffles:			
Arroyo Bridge	1.90	1.94	1.60
River Mile 73½	1.04	1.67	1.00
Bridge below Hallton	1.22	1.00	1.14
River Mile 67+	0.96	3.75	1.00
Millstone Bridge	1.20	—	—
Cooksburg Bridge	—	0.77	—
Average velocity in rapids, V_r	1.26	1.85	1.18
$\overline{V} = \frac{3 \times V_p \times V_r}{V_p + 2V_r}$ $\overline{V}$ in fps =	0.91	0.54	0.50
$\overline{V}$ in mph =	0.62	0.37	0.34
Figures based on U. S. Engineers data:			
Discharge in cfs per sq mi at Cooksburg	0.50	0.88	
	Chip velocities in miles per hour		
Reach B, near Cooksburg	0.82	1.12	
Reach C, near Millstone	0.72	1.05	
Reach D, near Hallton	0.96	1.15	
Average	0.83	1.11	

Note: Average stream velocities are taken as 80% of above chip velocities

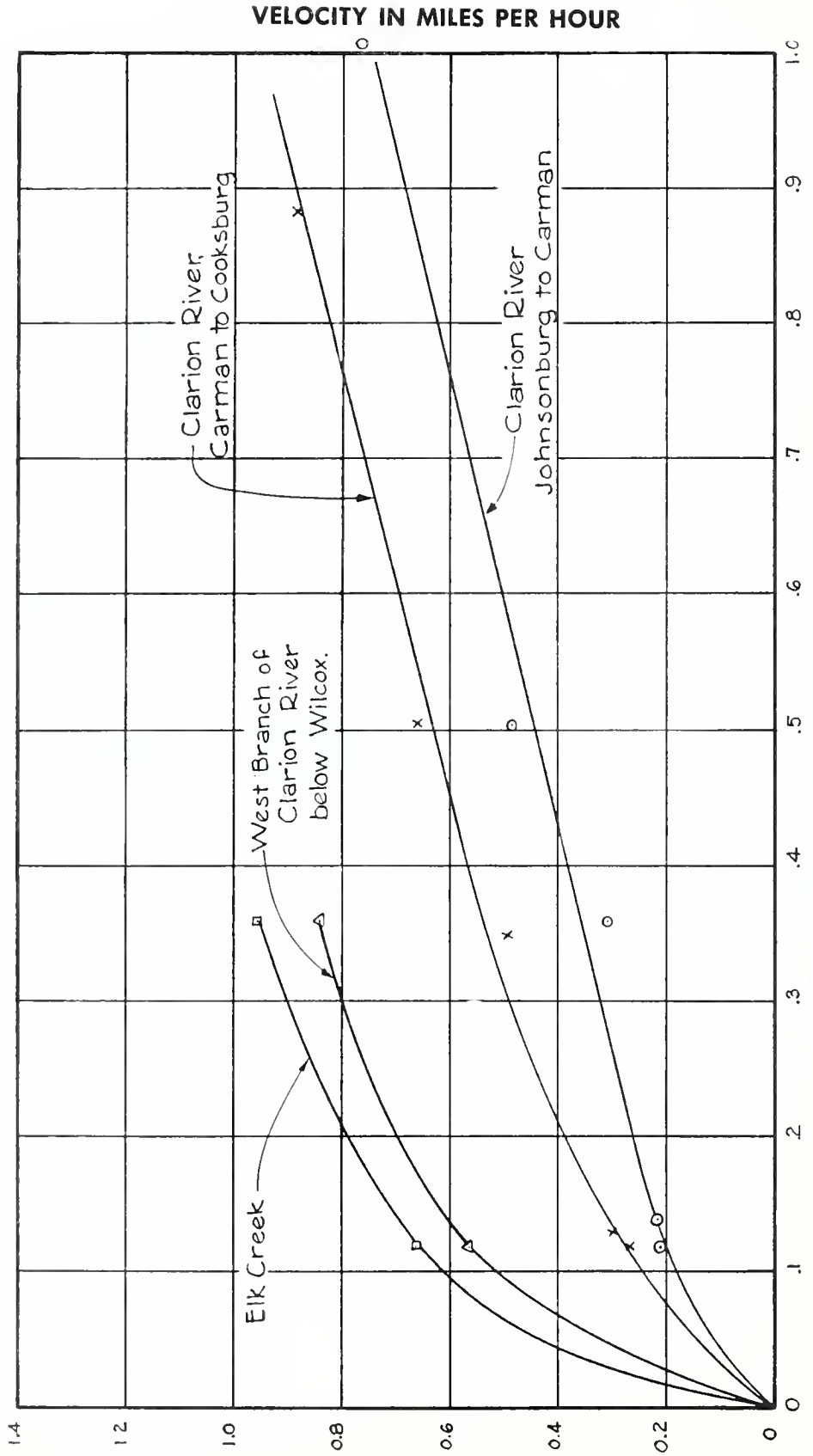

FIGURE 6. CLARION RIVER VELOCITY STUDIES

in Elk Creek, which is the steepest stretch of stream considered in these studies, were greater than in the West Branch, which in turn gave higher velocities than in the main river.

WATER ANALYSES OF THE CLARION RIVER SYSTEM

Many analyses of the waters of the Clarion River and its tributaries were made in the traverses conducted by the Pennsylvania Department of Health, U.S.P.H.S., and the New York and Pennsylvania Company, as mentioned in Chapter I of this report. The detailed data and analyses of previous traverses will not be repeated in this report, but as shown hereinafter we shall present the results computed from such data. Much of the previously obtained data has been useful to us and we have studied and coordinated such results with our own data. None of the previous traverses, however, could be used, in themselves, to determine the rates of deoxygenation and reaeration. To secure such data, therefore, it was necessary for us to run at least one special traverse.

The sampling stations established by the Department of Health were used insofar as possible for our traverses, but in order to get a more complete picture of the suspected rapid recovery of the river in its first few miles, we added several new sampling stations in the reach between Johnsonburg and Carman and a few other new stations downstream. The sampling stations used in our surveys are listed in Table 2 and shown by encircled letters on the general plan (Fig. 1) and profile (Fig. 4). The selection of the Grant Street bridge at Johnsonburg as the initial sampling point may be subject to question, inasmuch as it is only about 1,200 ft downstream from the point of discharge of the main ditch at the paper mill. Before selecting this station, however, we observed that, during periods of low flow in the river when almost all of the stream flow passes through the paper mill, there is an effective mixing of the wastes and water before they reach the Grant Street bridge. The river makes several bends in this stretch and at low flows there are several short stretches of rapids which tend to cause thorough mixing. It is to be noted that the U.S.P.H.S. also used this sampling station.

On all of the previous traverses, samples were taken along the whole length of the river on one day. Inasmuch as stream velocity in the Clarion River is quite slow during periods of low flow, being in the general magnitude of 5 to 10 miles per day during early autumn, it is apparent that samples taken all along the river on any one day do not represent the same water or the same pollution load. We decided, therefore, to try to follow the same pollution slug downstream and sample it for analysis as it passed each sampling station. Through and below Piney Reservoir, however, it was not deemed advisable to try to make our samples coincide with the time of flow because of the intermittent manner in which water is released from Piney Dam. Inasmuch as the major source of pollution at Johnsonburg is contributed for seven days per week and inasmuch as the discharge of tannery wastes at Wilcox and Ridway are equalized during week days, we reasoned that a sampling traverse should be started at Johnsonburg not earlier than Tuesday of any week and should pass Ridgway not later than Friday. Sampling traverses of Elk Creek and West Branch were conducted in the same manner, but since these streams are short and their velocities swift, only one day was required for each traverse.

There was some question as to whether it was necessary to follow a pol-

lution slug exactly as it passed downstream. Such a procedure might require sampling during night time or early morning hours at certain stations. While it is true that the strength of wastes discharged at the paper mill varies widely in short periods of time depending upon overflows in the soda mill and weak sulfite waste liquor (SWL) drainage from the sulfite blow pits (see Chapter VI for a description of the processes and wastes), it was logical to assume that the continuous week-day operation of all processes at the mill would tend toward reasonably constant pollution in the river, especially after longitudinal mixing in the first reaches has caused minor slugs to be equalized. This supposition was checked by a 24-hour test of the river water about one mile below Ridgway, the results of which are shown in Table 5. The relative constancy of the organic load in the river at this point, as measured by BOD and equivalent sulfites, indicated to us that it would not be necessary to sample at the exact theoretical time, as long as we stayed approximately with the slug.

Discussion of 1948 Traverses

Our sampling schedules were arranged, therefore, to follow approximately the flow of the river. Two such traverses of the Clarion River were made; the first being a partial traverse of the upper river on September 22-25, 1948, which had to be discontinued above the mouth of Toby Creek because of a shortage of BOD bottles, and the second being a complete traverse from Johnsonburg to St. Petersburg on October 13-19, 1948. The results of analyses of samples taken on these traverses are presented in Tables 6 and 7. No rain occurred during the time of sampling at any station upstream from Piney Reservoir and the stream flow in cfs per sq mile was relatively constant during these periods of sampling. Rain did occur, however, when samples were being taken in Piney Reservoir, but such dilution should not have affected these samples inasmuch as the volume of polluted water in Piney Reservoir was so great in proportion to the rain water dilution and samples were obtained at about half depth. Traverses were also made of Elk Creek and West Branch, as shown in Table 8.

The following discussion of the results of Tables 6, 7 and 8 is presented to point out significant analyses and trends. These comments also apply, in general, to the results of traverses conducted by others.

With the exception of the stretch between Johnsonburg and the mouth of Riley Run, the temperature of the water in the Clarion River and its tributaries was about normal for the season of the year. The temperatures fluctuate from day to day, and from hour to hour during a day, depending upon the air temperature and radiation from the sun. Inasmuch as all samples were taken in the daytime, the recorded temperatures may be slightly higher than the 24-hour averages. Traverses made by the New York and Pennsylvania Company in 1947 showed that temperatures of 25° C were not uncommon during July and August throughout the length of the Clarion River. Table 6 shows a 14° C increase between the temperatures observed on East and West Branches and at the main river sampling station at Grant Street bridge. This increase is caused by the discharge of hot process waters and water used for cooling purposes. Except for this rise at Johnsonburg, pollution by temperature change is not a problem in the Clarion River or its tributaries.

TABLE 5. RESULTS OF 24-HOUR TEST OF CLARION RIVER WATER BELOW RIDGWAY

Time of Sampling, Sept 16-17, 1948	*Temp. of Water °C*	*pH*	*Equivalent Sulfites, in ppm of SO_3*	*Dissolved Oxygen in ppm**	*B.O.D. 5-Day 20°C in ppm*
8 AM	20	7.0	4.85	0.36	81.7
10 AM	22	7.1	4.66	0.21	89.3
Noon	22	7.1	5.41	0.28	89.9
2 PM	25	7.0	5.88	0.0	90.3
4 PM	24	7.1	5.41	0.0	93.1
6 PM	23.5	7.0	5.02	0.0	83.9
8 PM	21.5	7.0	5.02	0.0	89.3
10 PM	21	7.0	4.85	0.0	89.3
Midnight	21	7.0	5.97	0.0	98.7
2 AM	20	7.0	5.41	0.0	94.9
4 AM	18	7.2	5.60	0.0	106.7
6 AM	18	7.0	5.60	0.0	93.5

Other analyses of composite sample:

	Total	*Fixed*	*Volatile*
Total solids, ppm	1325	773	552
Suspended solids, ppm	83	43	40
Dissolved solids, ppm	1242	730	512
Methyl orange alkalinity, ppm	263	—	—

NOTE: Samples taken at sampling station L, commencing on Thursday, September 16, 1948. The weather was fair and warm, and there had been no rain for several days. River discharge at Ridgway gaging station was about 52 cfs, or 0.17 cfs per sq. mi.

* By alkaline-hypochlorite modification.

For all of the samples taken during our traverses the maximmum pH value was 8.17 in the West Branch below Wilcox and the minimum pH was 6.56 at the Grant Street bridge, Johnsonburg. In general, the pH values of the samples of river water were quite close to 7.0. A study of the data obtained by others reveals that for all traverses a maximum pH value of 8.6 was obtained by the U.S.P.H.S. at Grant Street bridge. The U.S.P.H.S. also obtained the minimum value of any traverse, which was pH 4.7 at Portland Mills on the Clarion River. These two extreme values are considered to be very rare. The low pH value at Portland Mills may have been due to improper mixing of the Toby Creek water. With the exception of the acid streams, therefore, it is apparent that the present discharge of industrial wastes into the Clarion River and its tributaries does not change the pH values of the waters so as to cause any harmful or inimical effects.

Upstream from Johnsonburg, the West Branch shows a somewhat higher alkalinity than does the East Branch, attributable to the fact that the East Branch is unaffected by industrial wastes or municipal sewage. For a discussion of hardness in the East and West Branches, see Chapter V. At Johnsonburg the alkalinity is increased markedly because of the paper mill wastes. This alkalinity is sustained somewhat by wastes at Ridgway, but it gradually decreases downstream as a result of dilution, especially by acid streams such as Toby Creek. At no point were alkalinity concentrations found to be sufficient to injure aquatic life or to cause excessive damage to water supplies.

Rate of Dissipation of Sulfites

The weak sulfite waste liquor (SWL) discharged by the paper mill contains sulfites, polythionates and other reducing compounds, which we have measured collectively as "equivalent" sulfites. These reducing compounds are not in themselves inimical to the stream, but they are indicative of heavy pollution by sulfite waste liquors, and they contribute to the BOD of the wastes discharged at the paper mill. In a stream subjected to aeration, these compounds gradually disappear as they are oxidized to sulfates. In both of our traverses the equivalent sulfites persisted to the mouth of Toby Creek. In a solution containing a great excess of dissolved oxygen, it is known that sulfites are oxidized to sulfates in a true unimolecular reaction at a fairly rapid rate. In the Clarion River between Johnsonburg and Toby Creek, however, the availability of dissolved oxygen is severely limited; and the rate of the reaction is correspondingly reduced. The rate of dissipation of the equivalent sulfites on both traverses is shown graphically on Fig. 7. By way of comparison, we subjected a sample of paper mill wastes to diffused-air aeration and found that the sulfite concentration decreased from 22 ppm to 7 ppm in two hours of aeration and then remained approximately constant for four additional hours of aeration.

Dissolved Oxygen & BOD Content

In the September traverse, the dissolved-oxygen content of the Clarion River waters was completely dissipated by pollution at Johnsonburg and did not reappear until the waters reached the sampling station below Ridgway. The recovery at Ridgway was probably due to dilution from Elk Creek, inasmuch as the oxygen showed a further decrease at Carman. In the October traverse, when the water temperature was much lower, oxygen reap-

TABLE 6 ANALYSES FOR SAMPLING TRAVERSE OF UPPER CLARION RIVER – SEPTEMBER 22-25, 1948

Sampling Point (on Clarion River unless noted)	Date & Hour 1948	Temp. of Sample °C	Discharge mgd	pH	Alkalinity to pH 4.3 as ppm of $CaCO_3$	Equivalent Sulfate ppm	Dissolved Oxygen ppm	Biochemical Oxygen Demand: 5-day B.O.D. ppm	k_1 per day	L ppm	k_1L ppm/day	Total Solids: Total ppm	Fixed ppm	Volatile ppm	Suspended Solids: Total ppm	Fixed ppm	Volatile ppm	Dissolved Solids: Total ppm	Fixed ppm	Volatile ppm	Appearance	Odor
East Branch at First Avenue Bridge in Johnsonburg	3:45 PM Sept. 22	16	11.0	7.70	20	0	10.24	1.95	0.125	2.46	0.308	111	62	49	6	3	3	105	59	46	No perceptible color	Not perceptible
West Branch at Concrete Bridge near Rolfe	4:35 PM Sept. 22	16	9.4	7.35	54	0	10.05	2.30	0.148	2.97	0.440	1550	1452	98	18	6	12	1532	1446	86	No perceptible color	Not perceptible
Grant Street Bridge, Johnsonburg	9:50 AM Sept. 23	10.5	20.5	6.56	142	13.7	0.0	410	0.108	516	55.8	3000	1360	1630	332	140	192	2668	1220	1438	Grayish-brown, very turbid	Strong sulfite odor
Below mouth of Power's Run	11:30 AM Sept. 23	16	21.8	6.95	171	9.5	0.0	258	0.130	337	43.8	2125	1281	844	356	160	196	1769	1121	648	Grayish-brown, turbid	Strong sulfite odor
Above Riley Run	3:55 PM Sept. 23	18.2	22.7	7.05	162	5.8	0.0	164	0.207	192	37.7	1818	1328	490	180	101	76	1638	1224	414	Pinkish-gray, turbid	Strong sulfite odor
Ridgway Elec. Co. Dam.	10:40 AM Sept. 24	13.2	24.1	7.00	161	5.4	0.0	133	0.216	132	32.8	1692	1302	390	88	42	46	1604	1260	344	Yellowish-gray, turbid	Strong sulfite odor
Below Ridgway, + 1.0 miles	2:45 PM Sept. 24	15	31.1	7.35	157	2.8	2.3	62.9	0.253	70.0	17.7	1171	890	281	80	36	44	1091	854	237	Lemon color, moderately turbid	Moderate sulfite odor
Above Toby Creek	10:00 AM Sept. 25	13	36.2	7.40	166	2.0	9.8	71.6	0.268	79.2	21.2	1395	874	521	60	16	44	1335	858	477	Grayish, turbid	Moderate sulfite odor

TABLE 7. ANALYSES FOR SAMPLING TRAVERSE OF ENTIRE CLARION RIVER—OCTOBER 13-19, 1948

Sampling Point on Clarion River	Date & Hour 1948	Temp. of Sample °C	Discharge mgd	pH	Alkalinity Equivalent to pH 4.3 as Sulfate ppm of $CaCO_3$ ppm	Dissolved Oxygen ppm	% sat.	Biochemical Oxygen Demand 5-day B.O.D. ppm	k_1 per day	f. ppm	Total Solids Total ppm	Fixed ppm	Volatile ppm	Suspended Solids Total ppm	Fixed ppm	Volatile ppm	Dissolved Solids Total ppm	Fixed ppm	Volatile ppm	Appearance	Odor
Grant Street bridge, Johnsonburg	10.10 AM Oct. 13	27	33 2	7 90	218	72 4	0	0	337	0 119	420	50 0	2328	1478	818	408	190	218	1920	1288	640	Light brown, highly turbid	Strong sulfite odor
Below mouth of Power's Run	11.20 AM Oct. 13	12	31 4	7 90	120	20 8	0	0	241	0 143	285	40 8	1925	1218	727	231	18	186	1741	1200	541	Yellow brown, very turbid	Strong sulfite odor
Just above mouth of Riley's Run	2:55 PM Oct. 13	14 5	33 8	7 05	136	14 6	0 96	9.3%	165	0.167	194	31 4	1868	1291	566	168	128	48	1692	1170	522	Gray brown, turbid	Strong sulfite odor
Below Riley's Run about $\frac{1}{4}$ mile	4:00 PM Oct. 13	16	34 8	7 05	143	13 4	1 45	13.9%	160	0 156	190	29 6	1927	1361	566	260	110	150	1667	1251	416	Gray brown, turbid	Moderate sulfite odor
Forebay, Ridgway Elec. Co. dam	10:05 AM Oct. 14	12	35 7	7 22	150	6 9	0 73	6.8%	149	0.161	170	28.8	1659	1150	509	188	48	140	1471	1042	429	Gray brown, turbid	Moderate sulfite odor
Below Ridgway about 1.0 mile	2:10 PM Oct. 14	14	46 5	7 25	120	5 3	1 84	17 2%	88	0 211	96	20 3	1168	826	338	72	16	56	1092	810	282	Gray brown, turbid	Moderate sulfite odor
Just above mouth of Toby Creek	10:05 AM Oct. 15	11 5	47 0	7 01	113	4 5	1 25	11.4%	67	0 180	78	14 1	1176	810	116	52	—	—	1071	—	—	Grayish, slightly turbid	Moderate sulfite odor
Arroyo bridge	3:35 PM Oct. 15	13	68 0	7 12	66	0 6	3.05	28 8%	44	0 191	50	9 6	968	668	270	84	52	52	884	666	218	Grayish, slightly turbid	Moderate sulfite odor
Millstone bridge	5:20 PM Oct. 16	12	86 8	8 19	80	0	5.76	53 4%	29	0.165	35	5 7	671	422	249	68	27	45	603	395	208	Slight pinkish tint, slightly turbid	Earthy
Clarington bridge	11:10 AM Oct. 17	12.5	96 5	7 03	69	0	5.81	48.8%	18 4	0 112	26 8	3 0	729	111	315	42	8	34	687	406	281	Pink gray, slightly turbid	Earthy
Cooksburg bridge	12:00 Noon Oct. 17	12 5	123 0	7 09	68	—	6 66	62 3%	10 4	0 131	13 6	1 82	576	376	200	41	20	21	532	356	176	Pink gray, slightly turbid	Slightly earthy
Bridge at mouth of Mill Creek (Piney Reservoir)	11:10 AM Oct. 18	13	162 5	7 09	48	—	5.72	54 0%	1 7	0 075	2 80	1 21	458	217	241	12	0	12	446	217	229	Pink gray, slightly turbid	Very earthy
Route 966 bridge, Clarion (Piney Reservoir)	11:55 AM Oct. 15	15	164 0	6 90	47	—	3 49	35 2%	1 15	0 146	1 66	0.24	382	286	96	26	0	26	356	286	70	Pink gray, slightly turbid	Very earthy
At Piney Dam outlet	1:15 PM Oct. 18	15	172 0	6 90	14	—	1.57	15 4%	0	—	—	—	332	250	82	88	—	—	244	—	—	Pink gray, slightly turbid	Very earthy
Piney bridge, below dam	11:40 AM Oct. 19	12	—*	7 12	18	—	3.82	35 6%	1 13	—	—	—	356	229	127	8	8	0	348	221	127	Light-straw color, very slightly turbid	Faint earthy
Callensburg bridge	12:15 PM Oct. 19	10 5	—*	7 05	14	—	9 37	83 7%	2 64	—	—	—	278	172	106	0	0	0	278	172	106	Light-straw color, very slightly turbid	Faint earthy
St. Petersburg bridge	1:10 PM Oct. 19	10	—*	7 09	20	—	10 92	96 4%	1 84	—	—	—	280	202	78	4	4	0	276	198	78	Light-straw color, very slightly turbid	No perceptible odor

TABLE 8 ANALYSES FOR SAMPLING TRAVERSES OF WEST BRANCH AND EIK CREEK – OCTOBER 5-6, 1948

Sampling Point	Date & Hour 1948	Temp. of Sample °C	Discharge mgd	pH	Alkalinity to pH 4.3 as ppm of $CaCO_3$	Dissolved Oxygen ppm	Dissolved Oxygen % sat.	Biochemical Oxygen Demand 5-day B.O.D. ppm	Biochemical Oxygen Demand k, per day	Biochemical Oxygen Demand L ppm	Biochemical Oxygen Demand k.L ppm/day	Total Solids Total ppm	Total Solids Fixed ppm	Total Solids Volatile ppm	Suspended Solids Total ppm	Suspended Solids Fixed ppm	Suspended Solids Volatile ppm	Dissolved Solids Total ppm	Dissolved Solids Fixed ppm	Dissolved Solids Volatile ppm	Appearance	Odor
WEST BRANCH																						
Railroad Bridge below mouth of Wilson Run	10.15 AM Oct. 5	10	4.56	6.80	52.0	10.06	89.0%	3.23	0.1975	2.43	0.48	1737	1131	606	80	50	30	1657	1281	576	Colorless but slightly turbid	Not perceptible
Below Wilcox about one mile	2.30 PM Oct. 5	10.1	4.83	8.17	62.1	9.87	87.4%	7.76	0.033	14.5	0.767	1785	1371	412	61	32	12	1721	1141	1101	Very slight color and turbidity	Not perceptible
Concrete bridge at Rolfe	4.30 PM Oct. 5	10	6.69	7.70	50.5	10.40	92.0%	2.86	0.0965	4.05	0.39	1771	1224	547	70	2	68	1701	1722	679	Clear	Not perceptible
ELK CREEK																						
About 10 + miles below St. Marys	11:30 AM Oct. 6	12	0.93	7.00	122	1.97	18.25%	35.0	0.128	65.2	5.8	719	503	216	80	36	44	639	467	172	Turbid with slight yellow green color	Faint swampy odor
Mohan Run bridge	4:00 PM Oct. 6	12	3.96	7.25	59	9.63	89.2%	3.20	0.139	4.58	0.64	305	551	158	8	0	8	297	158	146	Clear with faint yellow green color	Not perceptible
Wooden foot bridge near mouth	5:00 PM Oct. 6	12	4.74	7.19	50	9.95	92.1%	7.52	0.098	11.81	5.16	310	222	88	12	0	12	298	222	76	Slightly turbid, light green color	Faint salty odor

peared at the sampling station just above the mouth of Riley Run. It increased slightly just below Riley Run owing to the fact that Riley Run water, although high in BOD, contained about 3 ppm of oxygen. Deoxygenation in excess of reaeration decreased the dissolved-oxygen content down to Ridgway, but it rose somewhat when diluted by Elk Creek. There was a further sag to Toby Creek and then the dissolved oxygen began to recover rapidly as dilution from Toby Creek and Bear Creek entered. By the time the water reached Cooksburg, it had acquired 6.66 ppm of dissolved oxygen and was 62.3% saturated. Through Piney Reservoir, however, the dissolved-oxygen content decreased seriously and was only 1.57 ppm at the outlet point. This decrease is attributed to the low reaeration rate in the reservoir and to the high BOD of the benthal deposits (see special discussion and analyses of Piney Reservoir which follows). Below Piney Dam, the dissolved-oxygen content of the river was restored rapidly by reaeration, so that at St. Petersburg the water was almost saturated.

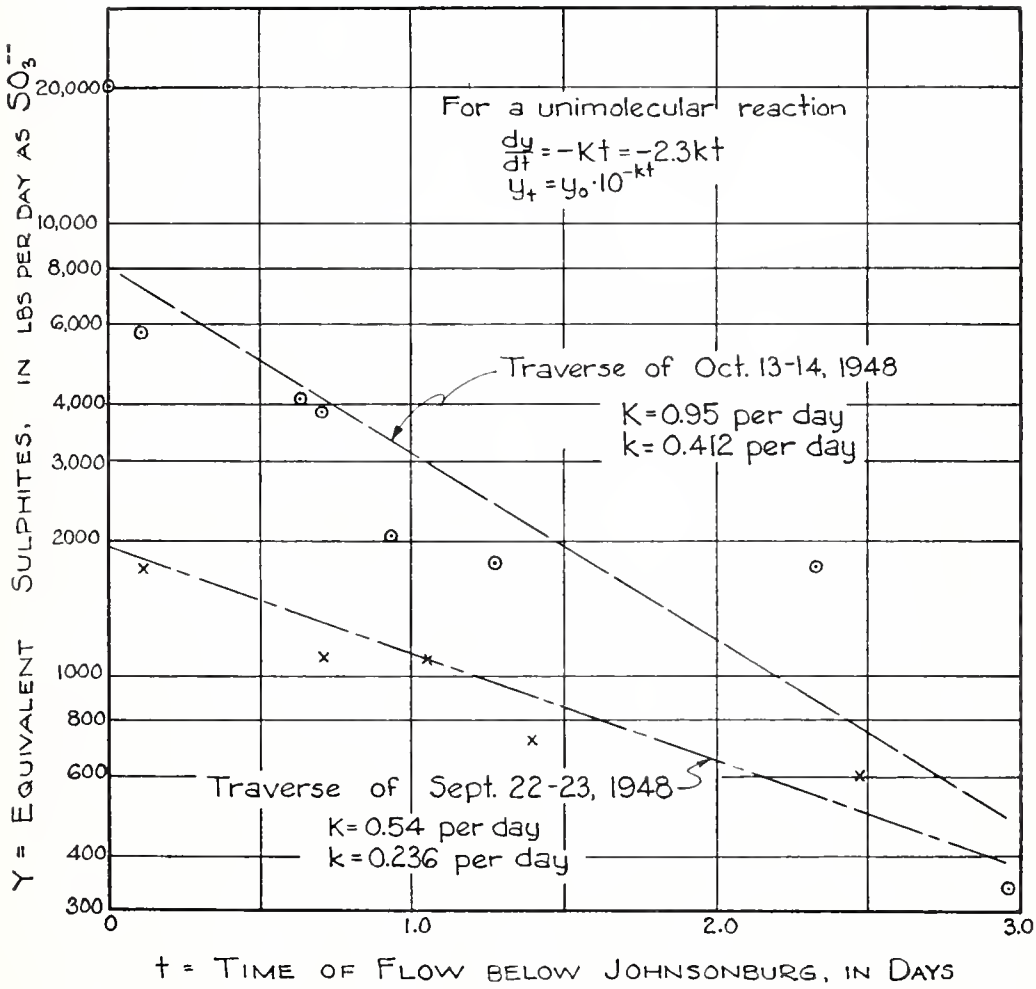

FIGURE 7.

RATE OF DISSIPATION OF EQUIVALENT SULFITES

The West Branch traverse of October 5, 1948, showed dissolved-oxygen contents in excess of 85% saturation at all points, even below Wilcox and the tannery. This stream is said to be stocked with trout and hence the dissolved-oxygen content therein is probably high at all times. The Elk Creek traverse of October 6, 1948, was not so favorable. About one mile below St. Marys the dissolved-oxygen content of the stream was only 1.97 ppm. In the 5.5-mile stretch to the next sampling station, however, the dissolved-oxygen content recovered to almost 90% of saturation.

In Tables 6, 7 and 8 the BOD value is expressed as 5-day BOD at 20°C. We have also shown k_1 and L values from the computed BOD curve, and the product k_1L which is the rate of deoxygenation in ppm per day. The 5-day BOD values were actual observed 5-day points and do not necessarily fall on the fitted curve as computed from the k_1 and L values determined statistically (see Fig. 2). It is to be noted that between Johnsonburg and Ridgway, the river water has a 5-day BOD value comparable to that of normal undiluted domestic sewage. Downstream from Johnsonburg, this BOD is decreased gradually as a result of dilution, stabilization by biochemical processes, and removal by physical processes such as sedimentation. The rate factor, k_1, of deoxygenation of incubated samples, was observed to decrease slightly as a result of pollution at Johnsonburg, but then to recover rapidly and to reach a value in excess of 0.20 per day. As recovery progressed, however, this rate decreased again. The observed values of k_1 are plotted on Fig. 8 and the values adopted for our deoxygenation and reaeration computations are shown by the broken line.

The product k_1L represents a rate of oxygen utilization, expressed as ppm per day. At a point in the stream where the rate of reaeration, k_2D, exceeds the rate of deoxygenation, k_1L, the dissolved-oxygen content of the stream will begin to increase. Table 7 shows that the dissolved oxygen does not begin to increase steadily until Arroyo bridge is reached, at which point the value of k_1L is 9.6 ppm per day. The 5-day BOD of the river water at the same station was 44 ppm from which the tentative conclusion may be drawn that in this reach the river is capable of recovering dissolved oxygen with at least 44 ppm of BOD content.

The BOD values which we obtained at the Grant Street bridge and near the mouth of Powers Run may appear, at first glance, to be extremely high. In the September traverse, the total BOD of the stream at Grant Street bridge (5-day BOD x million gallons per day (mgd) x 8.33) was 70,000 lbs per day and in the October traverse it was 93,000 lbs per day. The corresponding population equivalents, at 0.20 lbs of 5-day BOD per capita, are 350,000 and 465,000 persons respectively. We have examined the results of the data published by the U.S.P.H.S. and find that the 5-day BOD loadings at Grant Street bridge in October, 1940, were as follows:

	Discharge		*5-day BOD*		
Date, 1940	*cfs*	*mgd*	*ppm*	*lbs/day*	*Population equivalent*
Sept. 30	61	39.4	159	52,100	260,000
Oct. 8	58	37.5	292	91,200	456,000
Oct. 18	62	40.1	268	89,500	447,000
Oct. 28	53	34.2	128	36,500	182,000
Oct. 30	62	40.1	78	26,000	130,000
Oct. 31	62	40.1	216	72,200	361,000

It is evident, therefore, that our data in 1948 agreed reasonably well with the U.S.P.H.S. data in 1940 despite increases in production and higher BOD values resulting from the improved dilution water in the BOD test. A further comparison of BOD data from various traverses was made at all sampling stations, and the summary, presented in Table 9, shows that our data generally lie between the extremes of values obtained in previous traverses. Above the mouth of Riley Run, for example, which is the first sampling point below Johnsonburg used by the Department of Health and the New York and Pennsylvania Company, the average result obtained from all traverses is approximately of the same order of magnitude. Inasmuch as our results at this point, and other stations downstream, are not in excess of those obtained by the New York & Pennsylvania Company and the Department of Health, it is reasonable to believe that the results obtained for the two sampling stations upstream from the mouth of Riley Run are reliable. We conclude, therefore, that during September and early October, 1948, (and during most of the time when previous traverses were run), the 5-day BOD loading in the Clarion River just downstream from Johnsonburg was in the magnitude of about 80,000 lbs per day, equivalent to sewage from a population of about 400,000.

The traverse of West Branch showed a distinct increase in the 5-day BOD value below Wilcox and the tannery, but even with this increase the BOD in the stream is relatively insignificant and does not seriously affect the oxygen content. In Elk Creek about one mile below St. Marys, the BOD value was found to be 35 ppm, and it decreased rapidly as the water flowed downstream owing to natural purification in the stream. The further increase at the last sampling station was due to BOD discharge from sewers along Elk Creek in Ridgway. In subsequent surveys of Elk Creek, we found the 5-day BOD to be about 70 ppm below the Armour Leather Company and about 58 ppm below the Stackpole Carbon Company.

The complete analysis of all of the solids in a stream is frequently of great value in predicting its recovery. For that reason, we have determined total solids, suspended solids, and dissolved solids, with the fixed and volatile components of each. It is to be noted that the volatile solids content is very high below Johnsonburg, especially the dissolved volatile solids. This fact is attributed primarily to the digester liquors from the soda and sulfite mills at Johnsonburg. Volatile dissolved solids cannot be removed from a liquid waste by simple sedimentation but require biological metabolism and flocculation for effective removal. The ratio of the suspended to the dissolved volatile solids is a measure of the portion of the BOD which is susceptible of removal from a liquid waste by physical processes such as flocculation and sedimentation.

Attention is called to the high fixed dissolved solids content of the West Branch, even above Wilcox and the tannery. The analyses made by the Department of Health indicate that these dissolved minerals originate at the Otto Chemical Company plant at Sergeant on Wilson Run. We endeavored without success to determine the origin and nature of these salts, as explained in Chapter IV. Since these salts appear to have no significance from the standpoint of river water quality, the matter was not pursued further.

The quantitative determination of the odor of industrial wastes, or of river

TABLE 9. COMPARISON OF BOD RESULTS FOR VARIOUS RIVER SAMPLING TRAVERSES

Sampling Station on Clarion River	*Source of Data*[a]	*Time of Sampling*	*Number of Normal Samples*[b]	*Average 20° C 5-day B.O.D. in lbs per day*[c]
Grant St. Bridge, Johnsonburg	U.S.P.H.S.	Sept - Oct, 1940	6	61,100
	C.D. & M.	Sept - Oct, 1948	2	81,500
Below Mouth of Powers Run	U.S.P.H.S.	Sept - Oct, 1940	6	20,900
	C.D. & M.	Sept - Oct, 1948	2	57,000
Above Mouth of Riley Run	Pa. D. of H.	Sept - Oct, 1946	4	39,500
	N.Y. & Pa. Co.	July - Oct, 1947	7	29,000
	N.Y. & Pa. Co.	July - Aug, 1948	3	43,200
	C.D. & M.	Sept - Oct, 1948	2	38,600
Above Ridgway	U.S.P.H.S.	Sept - Oct, 1940	6	15,200
	N.Y. & Pa. Co.	July - Oct, 1947	7	25,000
	N.Y. & Pa. Co.	July - Aug, 1948	3	41,500
	C.D. & M.	Sept - Oct, 1948	2	35,400
Above Mouth of Toby Creek	Pa. D. of H.	Sept - Oct, 1946	3	19,600
	N.Y. & Pa. Co.	July - Oct, 1947	8	15,000
	N.Y. & Pa. Co.	July - Aug, 1948	3	21,200
	C.D. & M.	Sept - Oct, 1948	2	23,800
Arroyo Bridge	U.S.P.H.S.	Oct, 1940	5	41,000
	Pa. D. of H.	Sept - Oct, 1946	2	15,500
	N.Y. & Pa. Co.	July - Oct, 1947	7	11,800
	N.Y. & Pa. Co.	July - Aug, 1948	3	19,300
	C.D. & M.	Oct, 1948	1	24,900
Millstone Bridge	U.S.P.H.S.	Oct, 1940	5	18,400
	Pa. D. of H.	Sept - Oct, 1946	4	6,170
	N.Y. & Pa. Co.	July - Oct, 1947	5	6,150
	N.Y. & Pa. Co.	July - Aug, 1948	3	6,180
	C.D. & M.	Oct, 1948	1	21,000
Clarington Bridge	U.S.P.H.S.	Oct - Nov, 1940	5	17,700
	C.D. & M.	Oct, 1948	1	14,800
Cooksburg Bridge	U.S.P.H.S.	Oct - Nov, 1940	5	13,400
	Pa. D. of H.	Sept - Oct, 1946	4	4,560
	N.Y. & Pa. Co.	July - Oct, 1947	7	5,810
	N.Y. & Pa. Co.	July - Aug, 1948	3	15,100
	C.D. & M.	Oct, 1948	1	10,620

(a) U.S.P.H.S. = U. S. Public Health Service (House Document No. 266, 78th Congress)
C.D. & M. = Camp, Dresser & McKee
Pa. D. of H. = Pennsylvania Department of Health
N.Y. & Pa. Co. = New York & Pennsylvania Company, Inc.
(b) Abnormal results, such as those following a Labor Day weekend, were rejected.
(c) Average of values obtained from the product of B.O.D. (ppm) x stream flow (mgd) x 8.33 for each traverse.

waters highly polluted with industrial wastes, is extremely difficult. We attempted to measure the odor of samples of river water near Ridgway by means of the tests described by Standard Methods, but we were unable to make sufficient dilution to cause the odor to be non-discernible. In the U.S.G.S. Water Supply and Irrigation Paper No. 198 of 1907, George C. Whipple states that the odor of sulfite waste liquor is pronounced at a dilution of 1 to 500 and could be still detected until the dilution reached 1 to 25,000. It was decided, therefore, not to make quantitative determinations of odor and the results shown in Tables 6, 7 and 8 are qualitative only. The SWL odor is pronounced in the upstream reaches of the Clarion River but by the time the water reaches Piney Reservoir, it has a slight earthy odor, not disagreeable unless its origin is suspected.

The turbidity of the waters polluted by industrial wastes could have been measured quantitatively by techniques described in Standard Methods, but since the equipment for these tests was not available and turbidity is of secondary importance, the tests were not made. We attempted initially to determine color by quantitative tests but as pointed out by Standard Methods, such determinations on industrial waste effluents are difficult to evaluate and hence are unreliable. Therefore, the statements under appearance in Tables 6, 7 and 8 are descriptive only. It is to be noted that the appearance of the main river changes from a brown and turbid color to a grey and finally a pinkish grey or light straw color below Piney Dam.

It is recognized that the appearance and odor of the river waters are of great significance in shaping the judgment of the public as to the extent of pollution. It may be expected, however, that the measures recommended herein for the removal of suspended solids and BOD will in large measure remove the substances which cause odor, turbidity and color. After the abatement measures are in effective operation, the residual concentrations of these deleterious substances should be so small as to produce no objectionable effect upon the appearance and odor of the waters. If such is found not to be the case in any specific instance, the matter can be explored at that time to develop whatever refinements in treatment may be required to correct the objectionable appearance or odor. In the case of the Sinclair and Valentine Company plant at Ridgway, the corrective measures recommended herein as described in Chapter VIII relate specifically to color and turbidity as produced by pigments.

DETERMINATION OF EXTENT OF POLLUTION

In the foregoing section of this chapter the actual loadings of the Clarion River and its tributaries are shown as they were found at the time of our traverses and at the times of the surveys made by others. These loadings of pollutants have been shown to be excessive in several respects. In order to determine how much of various waste substances can be added at each point along the river without causing pollution therein, we have studied the assimilative capacity of the waters of the Clarion River and its tributaries with respect to biochemical oxygen demand, settleable and potentially settleable solids, temperature, odor, appearance and bacteria. The allowable loadings are discussed in detail below.

Reaction Rates of Water

From data obtained in the various river traverses, we have computed all of the rates of reaction necessary to determine the assimilative powers of the streams. For each traverse and at each sampling point the BOD, temperature, and dissolved-oxygen content of the stream were measured. From the results of our October traverse values of k_1 were computed as presented in Fig. 8. On the basis that these same deoxygenation rates applied at the time of the traverses run by others, we have computed the ultimate BOD, or L value, at each sampling station from the relationship shown in Fig. 2.

The details of the computations used in solving for the values of k_2 and k_3 for each reach of each traverse are too voluminous to present herein, but a summary of the values obtained by these computations is shown in Table 10. Illustrations showing methods of computation are presented in Examples 1 to 4. The value of k_3 is very high in the reaches between Johnsonburg and Riley Run, moderately high from Riley Run to Toby Creek, and relatively insignificant from Toby Creek to Cooksburg. In effect, these values of k_3 tell us that sedimentation and slime growths are very instrumental in reducing BOD in the first reach of the river and that these influences become progressively less significant with increasing distance downstream from Johnsonburg. A further discussion of this effect is presented below in the discussion of solids.

Table 10 also shows that the reaeration rate, k_2, is high in the reach from Riley Run to Ridgway and decreases gradually from there to Cooksburg. This decrease in k_2 is consistent with the fact that in the upper reaches of the stream the pools are shallower and the depth of flow, in general, is not as great as in downstream reaches. Inasmuch as the traverses between Grant Street bridge and Riley Run showed the stream to be anaerobic, it was impossible to compute reaeration rates in these reaches. We have assumed the reaeration rate in these two short upstream reaches to be the same as in the reach from Riley Run to Ridgway.

With the average deoxygenation and reaeration rates shown in Table 10 and the average values of discharge and temperature for the traverses run by the Department of Health, the New York and Pennsylvania Company and ourselves we have computed a theoretical oxygen-balance curve to compare with the actually observed dissolved-oxygen content in the various traverses. This theoretical curve serves as a check on our computations and the values selected for k_1, k_3 and k_2. The results are plotted on Fig. 9, which shows the theoretical curve and the actually observed dissolved-oxygen points for all traverses. In view of the fact that the theoretical curve based on the average reaction rates falls in the midst of the observed points, we have used the average rate coefficients from Table 10 in other computations to determine the allowable BOD loadings for the stream, and the effect of various types of treatment at the paper mill upon the oxygen balance in the Clarion River. See example No. 3.

EXAMPLE NO. 3

Oxygen sag computations used in the determination of the portion of the theoretical curve of oxygen balance in the Clarion River (shown

in Fig. 9) from just above Spring Creek (point a) to just below Millstone Creek (point b).

From Fig. 9:

Mean temperature of water below Riley Run T = 18°C
Mean Q = 0.27 cfs/sq mile
Dist. Spring Creek to Millstone Creek = 10.0 miles

Drainage areas: from USGS data

D.A. above Spring Creek	= 535 sq mi
D.A. of Spring Creek	= 88 sq mi
Total D.A. just below Spring Creek	= 623 sq mi
D.A. of incremental area between Spring and Millstone Creeks	= 48 sq mi
Total D.A. just above Millstone Creek	= 671 sq mi
D.A. of Millstone Creek	= 54 sq mi
Total D.A. just below Millstone Creek	= 725 sq mi

Flows computed from Drainage areas @ 0.27 cfs/sq mi

Total Q above Spring Creek	= 93.3 mgd
Q of Spring Creek	= 15.4 mgd
Total Q below Spring Creek	= 108.7 mgd
Q from incremental area	= 8.4 mgd
Total Q above Millstone Creek	= 117.1 mgd
Q from Millstone Creek	= 9.4 mgd
Total Q below Millstone Creek	= 126.5 mgd

From Fig. 6:

Velocity in Reach = V = 0.465 mph.

$$\text{Time of Flow, } t_1 = \frac{10.0}{0.465 \times 24} = 0.896 \text{ days}$$

From Table 10, Mean k values @ 20°C for reach are:

$k_1 = 0.15$
$k_2 = 0.70$
$k_3 = 0.00$

From Formulas on page 31, mean k values at 18°C for reach are:

$k_1 = 0.15\ (1.047)^{18\text{-}20} = 0.137$
$k_2 = 0.70\ (1.0159)^{18\text{-}20} = 0.678$
$k_3 = \qquad\qquad = 0.00$

From page 28:

$k_r = k_1 + k_3 = 0.137 + 0.00 = 0.137$ @ 18°C

$$10^{-k_r t} = \frac{1}{10^{(0.137)\ (0.896)}} = 0.754$$

$$10^{-k_2 t} = \frac{1}{10^{(0.678)\ (0.896)}} = 0.247$$

From calculation of previous reaches:

L just above Spring Creek = 13,800 lbs/day @ 20°C.

L of Spring and Millstone Creeks and incremental run-off estimated at 2.5 ppm

If incremental run-off in reach assumed as entering all at Spring Creek

ΔL @ Spring Creek = (2.5) (8.33) (15.4 + 8.4) = 496 lbs/day @ 20°C

Total L_a = 4.96 + 13,800 = 14,296 lbs/day

From formula on page 31:

Total L_a = (14,296) [1 + 0.02 (18-20)] = 13,720 lbs/day @ 18°C

From calculations of previous reaches:

D.O. above Spring Creek = 4.93 ppm

D.O. of saturation @ 18°C = 9.54 ppm

D.O. deficiency, D, above Spring Creek

D = 9.54 − 4.93 = 4.61 ppm

D = (4.61) (8.33) (93.3) = 3585 lbs/day

D of Spring and Millstone Creeks and incremental run-off estimated @ 0.95 ppm

D of Spring Creek = (0.95) (8.33) (15.4) = 122 lbs/day

Total D just below Spring Creek = 122 + 3585 = 3707 lbs/day

$$= \frac{3707}{(8.33)\ (108.7)} = 4.10 \text{ ppm}$$

D.O. just below Spring Creek = 9.54 − 4.10 = 5.44 ppm

D of incremental run-off = (0.95) (8.33) (8.4) = 67 lbs/day

Assuming incremental run-off enters at point a

D_a = 67 + 3707 = 3774 lbs/day

From Formula 9, page 30:

D_b = D just above Millstone Creek

$$D_b = \frac{k_r L_a}{k_2 - k_r} (10^{-k_r t} - 10^{-k_2 t}) + D_a \times 10^{-k_2 t}$$

$$= \frac{(0.137)\ (13{,}720)}{(0.678 - 0.137)} (0.754 - 0.247) + 3774\ (0.247)$$

$$= 1760 + 932 = 2692 \text{ lbs/day}$$

$$= \frac{2692}{(8.33)\ (117.1)} = 2.76 \text{ ppm}$$

D.O. just above Millstone Creek = 9.54 − 2.76 = 6.78 ppm

D of Millstone Creek = 0.95 ppm (see above) = (0.95) (8.33) (9.4) = 74 lbs/day

Total D below Millstone Creek = 74 + 2692 = 2766 lbs/day

$$= \frac{2766}{(8.33)\ (126.5)} = 2.63 \text{ ppm}$$

D.O. below Millstone Creek = 9.54 − 2.63 = 6.91 ppm

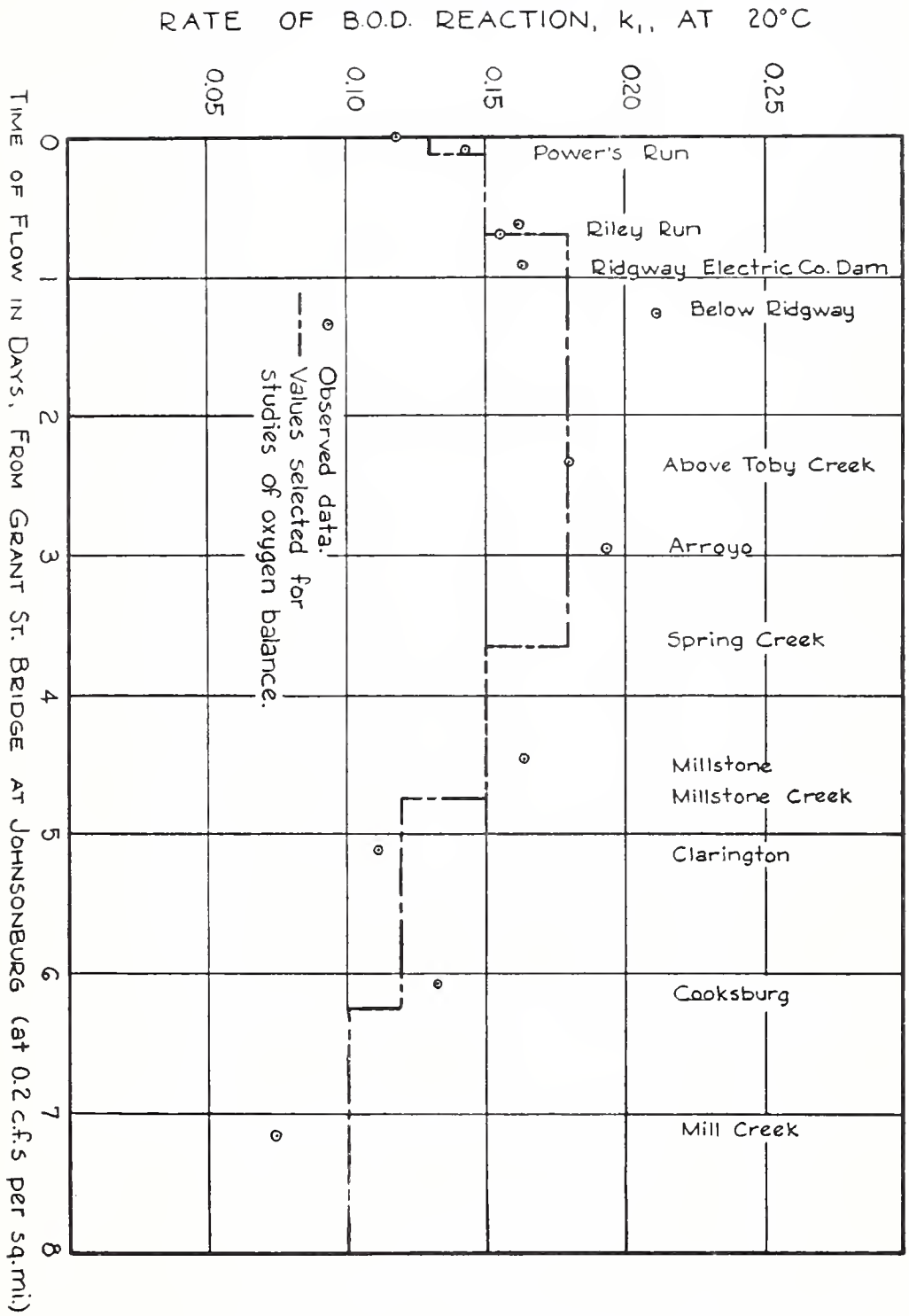

FIGURE 8.

EFFECT OF LAPSED TIME OF FLOW ON THE RATE OF BOD REACTION

TABLE 10. RATES OF DEOXYGENATION AND REAERATION AS COMPUTED FROM VARIOUS TRAVERSES OF THE CLARION RIVER

Reach	k_1 *at 20° C*	k_3 *at 20° C*				*Restoration rate,* k_2 *at 20° C*			
	C.D. & M.	*C.D. & M.*	*Pa. D. of H.*	*N.Y. & Pa. Co.*	*Average*	*C.D. & M.*	*Pa. D. of H.*	*N.Y. & Pa. Co.*	*Average*
Grant St. Bridge to Powers Run.....	0.13	0.84*	—	—	0.84	—	—	—	3.0**
Powers Run to Riley Run..	0.15	0.19	—	—	0.19	—	—	—	3.0**
Riley Run to Ridgway.....	0.18	0.06	0.11	0.14	0.10	2.7	2.7	3.4	3.0
Ridgway to Toby Creek...	0.18	0.05	0.11	0.17	0.11	—	—	1.4	1.4
Toby Creek to Arroyo....	0.18	—0.12	0.07	0.07	0.01	0.34	1.1	0.95	0.8
Arroyo to Millstone.....	0.15	—0.15	0.16	0.04	0.03	0.28	1.15	0.62	0.7
Millstone to Cooksburg....	0.12	0.15	0.005	—0.08	0.02	0.73	0.43	0.30	0.5

C.D. & M. = Camp, Dresser & McKee traverse of October, 1948
Pa. D. of H. = Average of Pennsylvania Department of Health traverses, 1946
N.Y. & Pa. Co. = Average of New York & Pennsylvania Company traverses, 1947
* = Average of September and October traverses
** = Estimated to be same as next reach downstream

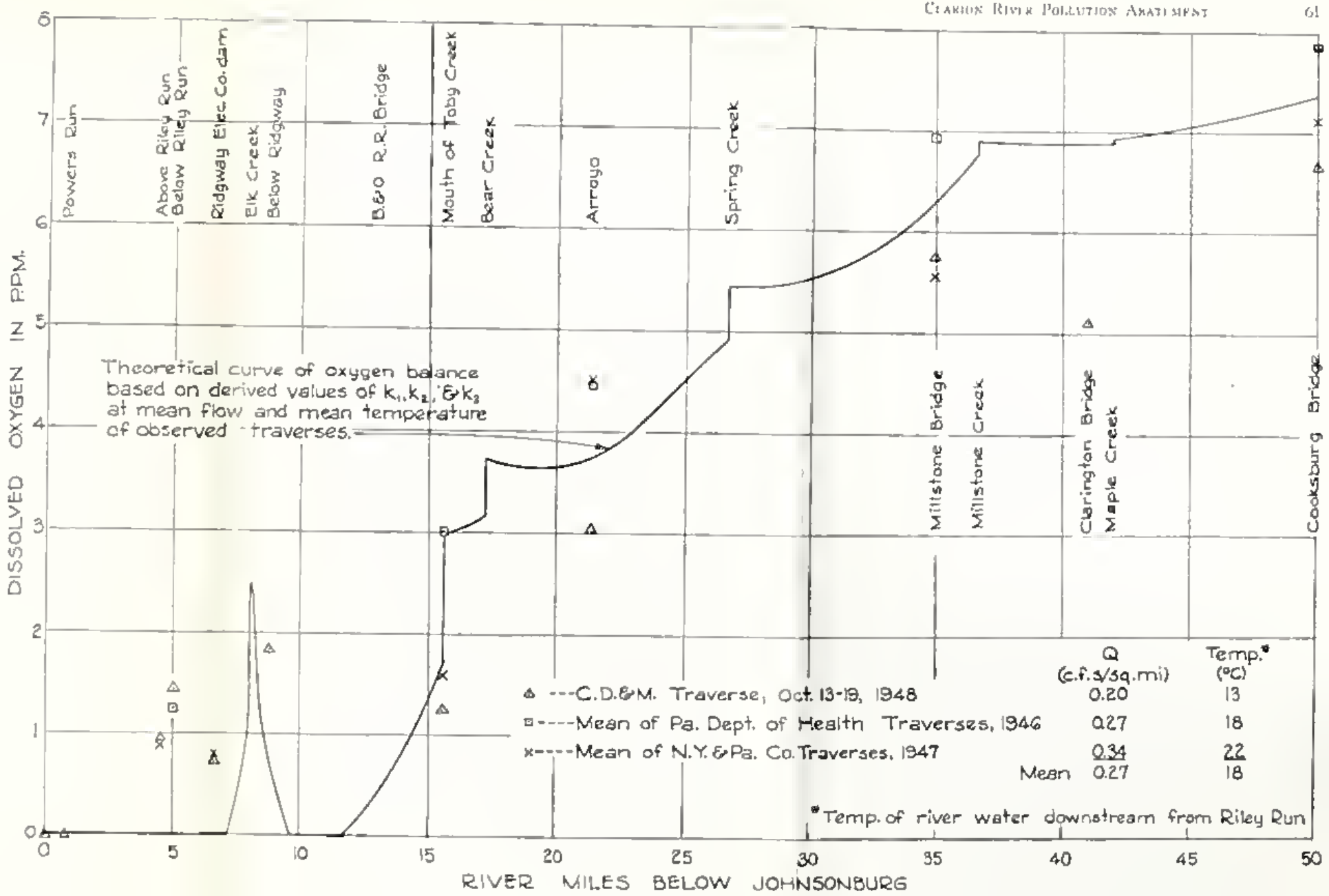

FIGURE 9. STUDY OF OBSERVED OXYGEN BALANCES IN THE CLARION RIVER.

It is realized that the values of k_1, k_2 and k_3 will be affected somewhat by varying degrees of treatment and by increased stream flows. Inasmuch as the value of k_1 fluctuates within narrow limits (generally between 0.12 and 0.18) it is not expected that the degree of treatment or the magnitude of stream flows will have much effect on this factor. The value of k_2 is affected by the depth of flow and the stream velocity, but inasmuch as we have determined it at relatively low flows, roughly of the same magnitude of flow to be expected in summer and early fall, this factor appears to be fairly well ascertained for the purposes of this study. When suspended solids are largely removed from the wastes, the value of k_3 will be decreased. In all of our oxygen balance studies described later in this report, we have assumed values of k_3 consistent with the degree of treatment being studied as shown in Table 20A.

The reaction rates for deoxygenation and reaeration were also determined for Elk Creek between St. Marys and Ridgway, based upon the results of three traverses, and for West Branch between Wilcox and Johnsonburg based on our data alone. The information from other traverses could not be analyzed for West Branch inasmuch as the U.S.P.H.S. sampled below Wilcox about a month before sampling at Rolfe, while the Pennsylvania Department of Health did not have a sampling station below Wilcox. The final results from the detailed computations, shown in Table 11, indicate that the reaeration constants are extremely high for both of these streams, as might be expected in view of their steep slopes and rocky beds.

TABLE 11. RATES OF DEOXYGENATION AND REAERATION FOR ELK CREEK AND WEST BRANCH

		Reaction rates at 20° C		
Stream	*Source of data*	k_1	k_3	k_2
Elk Creek	C.D. & M. (a)	0.134	1.46	5.4
	Pa. D. of H. (b)	—	6.02	25.9
	U.S.P.H.S. (c)	—	1.84	7.2
	Ave. for Elk Creek	0.134	3.11	12.8
West Branch	C.D. & M. (d)	0.075	1.88	8.7

(a) From one mile below St. Marys to Mohan Run bridge
(b) From one mile below St. Marys to Daguscahonda bridge
(c) From one mile below St. Marys to mouth of Elk Creek at Ridgway
(d) From one mile below Wilcox to concrete bridge at Rolfe

Table 11 also shows the values of k_3 to be very large, thus indicating that the streams remove much more BOD by flocculation, sedimentation and biological slime growths than is obtained by bacterial action in incubated samples. It appears, therefore, that the stream beds act somewhat like high-rate trickling filters.

In Piney Reservoir, the situation is quite the opposite. Using the average

values of BOD, dissolved oxygen, k_1, discharge and temperature as obtained at Mill Creek, Clarion and Piney Dam by the U.S.P.H.S., Pennsylvania Department of Health, New York and Pennsylvania Company, and our engineers, we computed the reaeration rate, k_2, to be 0.043 between Mill Creek and Clarion where the average depth is about 32 ft, and 0.022 between Clarion and Piney Dam where the average depth is about 68 ft. Thus the value of k_2 in this reservoir appears to vary approximately inversely with the depth.

Between Mill Creek and Clarion, the computations indicate the value of k_3 to be —0.095 and between Clarion and Piney Dam to be —0.106. These negative values of k_3 indicate that instead of BOD being removed by sedimentation, as occurred in upstream reaches, the benthal deposits in the reservoir are exuding products of anaerobic decomposition, such as fatty acids and amino acids, which mix with, and increase the BOD of, the overlying water. It is this action of the sludge blanket on the bottom of the reservoir which caused the dissolved-oxygen content during our October traverse in Piney Reservoir to drop from 6.66 ppm or higher at the upstream end of the reservoir to 1.97 ppm at Piney Dam. This matter will be explained below in more detail in the discussion of solids.

Assimilating Capacity of Waters

Having established the various factors controlling the rate of deoxygenation and reaeration in each critical stream, we next computed the allowable BOD loadings at each point where the increment of BOD was found to be significant. The following equation was used in the computations:

$$\log L_a = \log D_c + \left[1 + \frac{k_r}{k_2 - k_r}\left(1 - {}^{D_a}/_{D_c}\right)^{0.418}\right]\log \frac{k_2}{k_r} \quad (11)$$

where

L_a = allowable ultimate BOD loading at any point a in ppm at 25°C

D_c = critical oxygen deficit at 25°C to leave a residual dissolved-oxygen content of 4 ppm

D_a = initial deficit at point of loading at 25°C

k_r and k_2 = deoxygenation and reaeration rates at 25°C based on foregoing computations, with proper adjustments of k_3 to allow for treatment, sedimentation and aerobic slime growths.

The computations by means of the above equation yielded the allowable BOD loadings in terms of concentrations in the waters of the streams. In order to determine the permissible loadings in lbs per day, it was necessary to apply the allowable concentrations to the drought flows at 0.1 cfs per sq mile. For the Clarion River, the allowable loadings were also computed for drought flows plus 72 cfs to be obtained from the East Branch dam in low-flow regulation. The stream flows used in the computations are shown in Table 12. See example No. 4.

EXAMPLE NO. 4

Example of computations of allowable BOD loadings at Powers Run for Case E without East Branch Dam (see Table 20, p. 119 and Fig. 25).

T = River temperature = 25°C
D.O. @ saturation @ 25°C = 8.38 ppm
D.O. min. = 4.00 ppm
$D.O._a$ = 4.43 ppm (From calculation of previous reach see Fig. 25)
$D_a = 8.38 - 4.43 = 3.95$ ppm
D_c = Critical D = 8.38 − 4.00 = 4.38 ppm

From Table 20A, values of k @ 20°C are:
k_1 = p.15
k_3 = 0.13
k_r = 0.28
k_2 = 3.0

From Formulas on page 31, values of k @ 25°C are:
$k_2 = 0.15\ (1.047)^{25-20} = 0.1888$
$k_3 = 0.13\ (1.047)^{25-20} = 0.1636$
$k_r = k_1 + k_3 = 0.3524$
$k_2 = 3.0\ (1.0159)^{25-20} = 3.24$

From Table 12, page 62:
Q_{min} = 21.8 cfs
= 14.44 mgd

From Fig. 6: for q = 0.1 cfs/sq. mi
V = 0.176 mph

From Fig. 25: Distance to Powers Run = 0.75 miles

$$\frac{D_a}{D_c} = \frac{3.95}{4.38} = 0.902$$

$$k_2 - k_r = 3.24 - 0.35 = 2.89$$

$$\frac{k_r}{k_2 - k_r} = \frac{0.35}{2.89} = 0.122$$

$$(1 - \frac{D_a}{D_c})^{0.418} = (0.098)^{0.418} = 0.379$$

From Formula (11) page 60:

$$\text{Log } L_a = \log D_c + \left[1 + \frac{k_r}{k_2 - k_r}\left(1 - \frac{D_a}{D_c}\right)^{0.418}\right] \log \frac{k_2}{k_r}$$

$$= \log 4.38 + \left[1 + (0.122)\ (0.379)\right] \log \frac{3.24}{0.35}$$

$$= 0.642 + (1.046)\ (0.966)$$

$$= 1.652$$

L_a = 44.9 ppm @ 25°C

From page 31:

$L_a = 44.9 \div [1 + 0.02\ (25\text{-}20)]$
$= 40.8$ ppm @ 20°C

From Formula (3), page 24:

Allowable 5 Day 20°C BOD
$= L_a \left[1\text{-}10^{-(0.15)\ (5)}\right] = 0.823\ (40.8)$
$= 33.7$ ppm
$= 33.7 \times 8.33 \times 14.44 = 4{,}050$ lbs/day (see Table 13)

Residual at Powers Run from Johnsonburg loading:

$L_b = L_a \times 10^{-k_r t}$ (where $k_r = 0.35$ @ 25°C)

$t = \frac{0.75}{0.176} \times \frac{1}{24} = 0.178$ days

$L = 3{,}370 \times 10^{-(0.55 \times 0.178)} = 2{,}910$ (see Table 13)

Allowable Increment of Loading
$= 4{,}050 - 2{,}910 = 1{,}140$ lbs/day of 5 Day, 20°C BOD
(see Table 13)

TABLE 12. CRITICAL DROUGHT FLOWS AT FOCAL POINTS OF ORGANIC POLLUTION

Stream and Location	*Drought Flows in cfs Without East Branch Dam*	*With East Branch Dam*
West Branch below Wilcox	6.8	6.8
Elk Creek below St. Marys	1.2	1.2
Clarion River:		
Grant Street Bridge, Johnsonburg	20.5	92.5
Below Mouth of Powers Run	21.8	93.8
Above Mouth of Riley Run	22.7	94.7
Ridgway (above Elk Creek)	24.6	96.6

Extent of Organic Pollution

The total allowable BOD loadings computed as described above are shown in the first column of Table 13 and the total existing loadings as determined from our two river traverses and local surveys are shown in the second column. The difference between the loadings in the first two columns constitutes the extent of organic pollution and is shown in the third column of Table 13.

The allowable increment of BOD loading for each focal point has been computed by subtracting from the total allowable loading the residual from the upstream loading. The residual BOD from an upstream increment is given by the relation $L_b = L_a \cdot 10^{-k_r t}$. Where municipal sewage is involved, L_a is the present loading reduced by primary treatment. The allowable

TABLE 13. ALLOWABLE BOD LOADINGS AND EXTENT OF ORGANIC POLLUTION IN ELK CREEK, WEST BRANCH AND CLARION RIVER AT 25°C

(Expressed as 5-day, 20°C BOD in lbs per day)

Stream and Location	*Sources of Waste*	*Total Allowable Loadings*	*Total Existing Loadings*	*Extent of Pollution*	*Allowable Increments of Loading*	*Anticipated Increments of Loading*
West Branch at Wilcox	Village and tannery	911	440(1)	none	800	530(4)
Elk Creek at St. Marys	Borough, tannery, brewery	315	2,190	1,875	300	(3)

		Without dam	*With dam*		*Without dam*	*With dam*	*Without dam*	*With dam*	
Clarion River:									
Grant St. Bridge, Johnsonburg	Paper mill	3,370	13,200	81,500	78,130	68,300	3,150	12,200	(3)
Mouth of Powers Run	Borough sewage	4,050	14,800	57,000	52,950	42,200	1,140(2)	1,890(2)	595(4)
Mouth of Riley Run	Old paper wastes	4,800	17,800	38,600	33,800	20,800	3,155(2)	7,770(2)	1,240(4)
Ridgway	Borough and tannery	3,420	10,800	35,400	31,980	24,600	2,150(2)	2,530(2)	2,065(4)

(1) From local survey, assuming 25% of Wilcox sewage reaches stream.

(2) Based on allowable loadings or anticipated loadings at upstream points, whichever is lower, with decreases resulting from stream purification computed from $L_b = L_a 10^{-k_r t}$.

(3) See studies of proposed degree of treatment.

(4) Based on present loadings with primary treatment of domestic sewage.

increments of BOD loading are shown in the fourth column of Table 13, and the anticipated increments based on primary treatment of sewage are shown in the last column.

The results of the computations presented in Table 13 reveal that the allowable increments of loading exceed the anticipated increments at all points except Johnsonburg and St. Marys. Expressing these results in a more positive manner, we conclude from this table that the anticipated organic loadings at Wilcox, Powers Run, Riley Run and Ridgway are not of sufficient magnitude to cause pollution insofar as BOD is concerned. The table also shows gross organic pollution at St. Marys and Johnsonburg. For adequate abatement, BOD removal of about 85% at St. Marys and about 96% at Johnsonburg are indicated. After the completion of the East Branch dam, a BOD removal of only about 84% is indicated for Johnsonburg.

Sludge Deposits

A high content of suspended or dissolved solids in a stream may be harmful or inimical in several ways. Dissolved mineral solids in high concentrations may cause osmotic action on animal tissues, and certain types of minerals such as chlorides or nitrates may be a public health menace if present in sufficient quantities. Such a condition does not appear to obtain in the Clarion River and its tributaries, except in the acid streams. Dissolved organic solids are detrimental in that they provide a source of food for bacteria which in turn convert them to suspended solids in the form of bacterial bodies. All suspended solids, both mineral and organic, are potentially harmful in high concentrations in that they tend to settle in quiescent reaches and thus form unsightly sludge banks. The organic matter in such sludge banks then undergoes anaerobic decomposition with the resulting production of foul odors and the exuding of BOD to the stream. Furthermore, suspended solids cause turbidity which may inhibit algal growths and normal aquatic life. In our judgment, it is essential to remove all settleable solids from wastes being discharged into the Clarion River and its tributaries and to reduce the suspended-solids content as much as possible by means of primary sedimentation. It is essential even for municipal sewage in order to remove unsightly floating solids and to permit effective bacterial disinfection by chlorination. This conclusion is in keeping with the policy of the Sanitary Water Board to require at least primary sedimentation of all wastes discharged into the non-acid waters of the Commonwealth.

Dissolved solids and finely divided suspended solids present a problem more difficult of resolution because of the fact that bacterial action and flocculation will convert such solids into the settleable state. Thus it is possible to have the paradoxical situation where all settleable solids are removed by treatment plants and yet sludge banks form in the receiving stream. At Grant Street bridge in Johnsonburg, for example, Table 7 shows that the volatile suspended-solids content was 218 ppm whereas the volatile dissolved-solids content was 640 ppm, a total of 858 ppm of volatile solids. If 70% of the suspended solids were removed by sedimentation, the remaining volatile solids would be 705 ppm or about 82% of the original content before sedimentation. For optimum growing conditions of bacterial cells, it is known that approximately 77% of the food supply is converted to bacterial bodies and slimes and the remainder is burnt up to furnish the

energy required for growth. Therefore, approximately 77% of the volatile solids will be converted to bacterial and biological slimes, much of which constitute new settleable solids. Hence the calculations show that up to about 63% (i.e. 77% of 82%) of the organic content of sludge banks which originally formed in the river will still form despite primary sedimentation. This is an important concept and it has influenced to a great extent the recommendations contained in this report.

In the first reach of the Clarion River, between Grant Street bridge and Powers Run there is a reduction in the total 5-day BOD (see Table 9) of about 24,500 lbs per day based on our September and October traverses and corroborated in general by the other traverses. Only about 500 lbs per day of this can be accounted for by the rate of atmospheric reaeration and the remainder is removed by other means. This explains why there is a high value of k_3 in this reach. Computations have been made to determine whether the remainder of the removal can be accounted for by anaerobic decomposition of the organic matter removed by settling and adsorption on the bottom slimes. Assuming reasonable rates of anaerobic benthal decomposition and a benthal layer of 10% solids content, we have calculated the limiting organic sludge deposit in this reach (as of October, 1948) to be 175,000 cu ft, or an average depth of about 8 inches over the entire stretch. The limiting deposit would obtain when the rate of removal equals the rate of anaerobic decomposition. Since rapids will accumulate very little sludge, this calculation would indicate a limiting organic sludge blanket 10 inches to 12 inches deep in the pools. The limiting depth is not actually reached because of scour at high river stage about 50% of the time but the depths observed are consistent with the computed limit. Hence the tremendous reduction in BOD in this reach can be accounted for largely by sedimentation and adsorption, both of original settleable solids and of settleable solids formed by biological flocculation.

Effect of Piney Reservoir

The organic sludge deposits in the upstream reaches of the river gradually build up during low flows in the summer and fall months, despite a certain degree of stabilization by anaerobic action. In the winter and spring months, however, and during freshets, high stream flows and floods scour out much of this sludge and carry it downstream into Piney Reservoir where it resettles. Further decomposition in the reservoir is retarded during cold weather but is active the following summer. A study of the flow-duration curve indicates that flows of sufficient magnitude to start scour of the bottom deposits in Piney Reservoir do not endure for a sufficient period of time to remove an appreciable amount of the bottom deposits. It is evident therefore that organic sludge has been accumulating in Piney Reservoir for many years. The decomposition of these bottom deposits results in degrading the quality of the water in the reservoir.

A calculation of the deoxygenating effect of the sludge in Piney Reservoir was made on the basis of the negative k_3 values in the reservoir as described hereinfore. This computation showed that about 75 to 95% of the BOD at the Route 966 bridge in Clarion was attributable to the benthal deposits and only 5 to 25% was due to the remaining BOD of water from the Mill Creek sampling station. At Piney Dam, almost 100% of the BOD resulted

from benthal action. These calculations showed, furthermore, that the entire sludge blanket in Piney Reservoir was producing 15,000 to 30,000 lbs per day of 5-day BOD on the day of sampling. The computations indicate that the sludge deposited each summer in the upstream reaches of the river are of sufficient magnitude, when washed into Piney Reservoir, to account the next year for the observed critical drop in the dissolved-oxygen content of the reservoir.

Piney Reservoir is analagous to a huge sewage treatment plant comprising primary sedimentation (during high river stages), biological flocculation, secondary sedimentation and sludge digestion, with no sludge-removal mechanism. Hence it is like a gigantic septic tank except that there is now enough dissolved oxygen in the influent to allow a small amount of dissolved oxygen in the effluent. In past years, before the existing treatment works at the paper mill and tanneries were installed, it is reported that the effluent from Piney Reservoir was actually devoid of oxygen at times.

None of the foregoing figures measure accurately the assimilative capacity of the river or the reservoir for suspended or dissolved solids. However, the figures indicate that if all settleable solids are removed by primary sedimentation and if a decrease of volatile solids is accomplished by sufficient reduction of BOD at Johnsonburg to prevent the dissolved-oxygen content of the Clarion River from sagging below 4.0 ppm, then the problem of sludge banks and deoxygenation in Piney Reservoir (or such other reservoirs as may be built) will be resolved. A further discussion of this matter is contained in Chapter VI.

Temperature of the River

In the foregoing section of this chapter we have shown that increases of temperature in the Clarion River and its tributaries are insignificant, except at Johnsonburg where an increase of 14.5°C was registered in our September traverse and 14°C in our October traverse. It is recognized that this zone of high temperature in the stream may cause distress to fish and may act as a barrier to the travel of fish up or downstream past Johnsonburg. For that reason we have investigated the probable effect of this increase in temperature at Johnsonburg during periods of drought flow and also after the low flows have been materially increased by the dam presently being constructed at Glen Hazel.

By private correspondence, M. LeBosquet, Jr. of the U. S. Public Health Service has informed us that the heat-loss constant for the Clarion River as explained by him in the June, 1946 issue of the Journal of the New England Water Works Association, was found to be 8.8 btu per sq ft per hour per degree Fahrenheit excess in temperature of water over air. By similar computations we determined the heat-loss constant for our September traverse to be 4.2 and for our October traverse to be 12.1 btu per sq ft per hour per degree Fahrenheit excess. Our average value was 8.2, which checks Mr. LeBosquet's heat-loss constant quite closely.

While this constant is useful in estimating the rate at which heat will be dissipated, it does not reveal what excess of temperature might be expected at the point of discharge of the wastes. From the observed increases in September and October 1948 we have computed the temperatures which might be expected at Johnsonburg in July or August of any year when

drought flow occurs and also for drought flow plus 72 cfs from the East Branch dam. The results of these computations are presented in Table 14 and show that the resulting temperature in the stream at or below Johnsonburg will be inimical to aquatic life during drought flows; but when the new dam is in operation, the increase in temperature will only be about 6°C, which should not be of sufficient magnitude to harm fish life. At such times as the necessary degree of treatment to achieve proper BOD reduction is installed, it is estimated that the resulting temperature increase will be even less. We conclude therefore that pollution by temperature increase will not be a controlling factor.

TABLE 14. ESTIMATED TEMPERATURE INCREASES OF CLARION RIVER AT JOHNSONBURG

Month of Traverse	*Stream Flow in mgd*	*Observed Temperature Increase*	*Estimated Temp. Rise**		*Resulting Temp.**	
			Without Dam	*With Dam*	*Without Dam*	*With Dam*
Sept., 1948	20.5	14.5°C	22.4°C	5°C	47.4°C	30°C
Oct., 1948	33.2	14.0°	35.0°	7.8°	60°	32.8°
Averages			29°	6.4°	54°	31.4°

* during drought flows, at 25°C.

Color & Odor

The assimilative capacity of a stream for odors in industrial or municipal wastes is difficult to evaluate inasmuch as residual odor is a function not only of dilution but also of the masking effect of natural substances and the absorption of odoriferous molecules on biological growths, bottom deposits and carbon granules. Our surveys reveal that strong odors resulted from the wastes of the Otto Chemical Company at Sergeant (wood-distillate plant), the three tanneries, the brewery, the paper mill and the municipal sewage. Wilson Run and West Branch can apparently assimilate the wastes being discharged into them without noticeable unpleasant residual odors (except for the weekly slug discharged by the Otto Chemical Company, which is discussed in more detail in Chapter IV). At St. Marys, the heavy load of tannery, brewery and municipal wastes normally would cause Elk Creek to have a strong stench, but the finely divided carbon discharged into the creek from the carbon companies completely adsorbs these odors and renders the stream almost odor-free. If the carbon wastes are removed from the stream before other corrective measures are taken, Elk Creek will present an odor problem in and near St. Marys. With the program as recommended in this report, however, we anticipate that residual odors in Elk Creek will not be a problem.

The primary odor problem in the Clarion River basin is that arising from the sulfite waste liquors at the paper mill. As stated hereinbefore, a dilution of 25,000 to 1 is required to render strong SWL non-discernible, and weak SWL will require dilution roughly proportional to its BOD strength. If there were no treatment whatsoever of SWL at the paper mill it is estimated

that a stream flow of 7,430 cfs (36.4 cfs per sq mi) would be required at Johnsonburg to render the odor non-discernible. With the existing methods of treatment, a stream flow of 770 cfs (3.76 cfs per sq mi) would be required, but such high flows occur less than 15% of the time. For the high degree of removal of SWL which we recommend in this report, a stream flow of 148 cfs (0.72 cfs per sq mi) will still be required to avoid the SWL odor in the river reach a few miles below Johnsonburg. When the East Branch dam is completed this flow will be exceeded 80% of the time and hence only during dry months will the odor be discernible. This problem is discussed in more detail in the chapter dealing with the proposed program of pollution abatement at the paper mill.

Like odor, the color of industrial substances which can be assimilated by a stream without harmful or inimical effect is difficult of evaluation. Color and turbidity are problems primarily at the tanneries, at the ink plant in Ridgway and at the paper mill. Their relation to the degree of treatment recommended will be discussed in detail in the chapters pertaining to each establishment.

Coliform Bacteria

The only recent record of bacterial analyses of the waters of the Clarion River and its tributaries, to the best of our knowledge, is that obtained by the U.S.P.H.S. in 1940. Because the results of these analyses appear to be accurate and reliable and because the bacterial load in a river can be fairly well estimated from the number of persons served by sewers, bacterial analyses were not included in our program. Instead we have used the U.S.P.H.S. bacterial analyses in our studies, as described below.

The U.S.P.H.S. records give the concentration of coliform organisms (bacteria characteristic of the intestinal tract) in terms of most probable number (MPN) for each time of sampling. From the known discharges we have computed the total coliform content at each day of sampling and thus determined the geometric mean, inasmuch as bacterial analyses are based on geometric progressions. The results of these calculations, expressed as a percentage of the concentration at Johnsonburg, are plotted on Fig. 10 and compared with a typical die-off curve for summer months. The observed points are somewhat scattered but seem to follow the general die-off trend.

The number of coliform bacteria in fresh domestic sewage has been shown by past experience and experiments to be from 200 to 400 billion per capita per day. We have computed the number of coliform bacteria per capita per day at Johnsonburg and Ridgway based on the measured concentration in the river (with proper adjustment at Ridgway to allow for the residual from Johnsonburg) and these computations show 158 billion coliforms per capita per day at Johnsonburg and 78 billion coliforms per capita per day at Ridgway. Inasmuch as intestinal bacteria die off rapidly in sewers and in short stretches of the river, these computed per capita values are reasonable.

Knowing the MPN of bacteria per day being discharged at each community we then computed the bacterial removal required by treatment works to reduce the concentration in the river to less than 1,000 coliforms per 100 milliliters (ml) at drought flow, with and without the East Branch

dam. These calculations show that without the East Branch dam 99.93% of the coliform bacteria at Johnsonburg will have to be removed by treatment and with the East Branch dam, 99.71%. At Ridgway the kill will have to be 99.85% without the dam and 99.58% with the dam. At St Marys, 99.94% of the coliform bacteria must be removed from the borough's sewage caused to discharge into Elk Creek. All of these figures, being in the general magnitude of 99.9%, indicate that the proposed sewage treatment plants at Johnsonburg, Ridgway and St. Marys must incorporate some means to achieve effective disinfection in order to attain the high removal required.

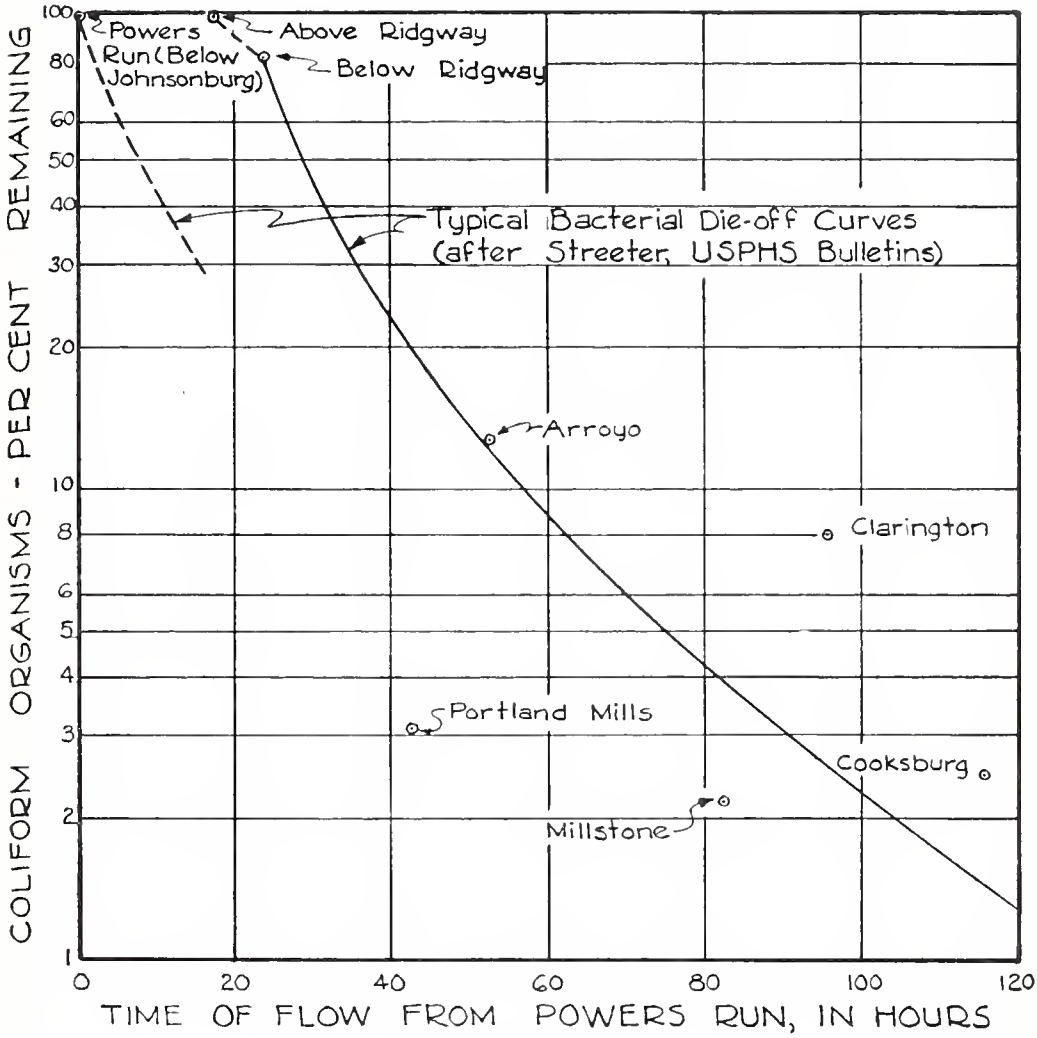

FIGURE 10.

BACTERIAL DIE-OFF IN THE CLARION RIVER

(Based on data contained in House Document 266, 78th Congress)

FOCAL POINTS OF POLLUTION

The river surveys and the surveys of the industries, described hereinafter, show that pollution of the Clarion River and its tributaries exists at the following focal points:

1. Wilson Run at Sergeant. Pollution in the form of sporadic discharge of BOD, dissolved solids, color and odor is contributed by the chemical company. Bacterial pollution is suspected from a few private sewers at the village of Sergeant.
2. West Branch at Wilcox. Bichemical oxygen demand from the tannery and village of Wilcox does not appear to be sufficient to cause pollution. Pollution might possibly be caused, however, by dissolved and mineral solids, color, odor and hardness emanating from the tannery and by bacteria from the village.
3. Clarion River at Johnsonburg. The paper mill and the borough contribute wastes in sufficient concentration to cause pollution with respect to BOD, suspended and dissolved volatile solids, temperature, color, odor and bacteria.
4. Elk Creek at St. Marys. Pollution in the form of BOD, solids, color, odor and bacteria is caused by discharges from the borough sewers, the carbon companies, the tannery, and the brewery.
5. Clarion River at Ridgway. The biochemical oxygen demand contributed by the borough and industries at Ridgway does not appear to be in sufficient concentration to cause pollution. However, the tannery, the ink plant and the borough of Ridgway discharge waste which may cause pollution with respect to solids, color, odor and bacteria.

Below Ridgway, there are no focal points of industrial pollution, the former wood-distillate plant at Hallton having been dismantled in October, 1948. There are, however, several villages including Portland Mills, Millstone, Clarington, Cooksburg, Callensburg and St. Petersburg from which some sewage or septic-tank effluents may reach the river and cause local concentrations of coliform organisms in excess of the allowable limits. A detailed investigation of such wastes was considered to be beyond the scope of our studies. The borough of Clarion has a sewerage system and a primary treatment plant with chlorination, the effluent from which discharges into Piney Reservoir. The available analyses of the reservoir waters do not reveal stream pollution from this source and our computations show that the BOD load from the borough of Clarion is negligible compared to the BOD contributed by benthal deposits in the reservoir. Consequently, we have confined our further studies to the focal points at and upstream from Ridgway.

The remainder of this report is devoted to a description of the type and quantity of waste discharged at each of the foregoing focal points and recommendations for the abatement of pollution at each industry and municipality.

CHAPTER IV.

WILSON RUN AT SERGEANT

The focal point of pollution most distant from the mouth of the Clarion River is at Sergeant on Wilson Run, about four miles southeast of Kane, where the Otto Chemical Company operates a wood-distillate plant. Bacterial pollution is also added at this focal point from the village of Sergeant. Each of these sources of pollution is discussed below.

OTTO CHEMICAL COMPANY

Description

The wood-distillate plant of the Otto Chemical Company at Sergeant is about 50 years old and has been renovated several times to modify processes in accordance with industrial demand. At the present time three materials are produced; unrefined wood alcohol, sodium acetate and charcoal. The raw materials used in production are beech, maple and cherry woods and soda ash. The plant operates 8 hours per day for about 260 days a year and employs about 20 men. A sketch of the drainage system of the Otto Chemical Company is presented in Fig. 11.

To start the manufacturing process, the wood is heated in gas-fed ovens to produce charcoal and volatile gases containing pyroligneous acid and wood tar. The charcoal is allowed to cool 48 hours in an air-tight chamber and an additional 48 hours in the open air. About 830 bushels of charcoal are produced per day. The volatile gases, driven off at a temperature of about 600°F, are then condensed and pumped to four storage vats. The cooling water for this operation is taken by gravity from a small dam along Wilson Run and returned through a ditch to Wilson Run, as shown in Fig. 11. The resulting liquid is then led to a tar still where the volatile constituents are driven off to leave a residue of tar. The molten tar with some water and impurities flows to two storage vats, as shown on the drawing, and then to a tar-water separator. The separated tar is then reclaimed and used as fuel in the stills. The water and impurities are drained to the nearby ditch.

The condensate from the tar stills is next mixed with soda ash, converting the acetic acid to sodium acetate to facilitate the further separation of the alcohol. The condensate then enters three alcohol stills where further vapors are driven off and condensed to produce a crude form of wood alcohol (approximately 100 gpd of 100-proof alcohol). Certain impurities in the alcohol are decanted and drained to an alcohol-decanting lagoon (see sketch). The liquid from the alcohol stills is then passed through three cloth-type filters to remove carbon black and other residual solids. The remaining water in the filtrate is driven off as steam and the resulting solution of sodium acetate is hardened in crystallizing crucibles, then pulverized and placed in containers for shipment. Approximately 3,000 lbs of sodium acetate are produced per day.

The carbon black from the filters is hosed out every day and discharged

to a primary evaporating lagoon. This primary lagoon has an overflow pipe leading to an adjacent secondary lagoon. Sludge from the lagoons is removed periodically and spread over the adjacent ground.

Once each week, generally early on Monday morning, the tar stills, alcohol stills, and acetate vats are flushed and the resulting wastes are discharged to a long ditch which empties into Wilson Run about one-quarter mile downstream from the plant. It is understood that the Otto Chemical Company had promised the Sanitary Water Board to pump this weekly flushing water into the secondary lagoon to prevent its discharge directly to the stream, but at the time of our survey wastes were still being discharged into the ditch.

The analyses reported in the Department of Health survey of October, 1946, show a great increase in dissolved mineral solids in Wilson Run as it passes the Otto Chemical Company. Our engineers noted a similar high dissolved-mineral content above Wilcox on October 5, 1948 (see Table 8), but Table 15 shows that on November 1, 1948, no abnormal values were observed. From the processes reported to our engineers by the assistant superintendent we were not able to discover a source of these mineral solids, and since the matter appeared to be of little consequence, it was pursued no further.

A survey was made of the industrial wastes at this plant on November 1, 1948, with the results of analyses as shown in Table 15. Samples were taken of the water of Wilson Run above and below the Otto Chemical Company, of the cooling-water ditch, and of the long ditch discharging about one-quarter mile downstream. Flows in the ditches were not gaged directly but have been estimated on the basis of the flow in Wilson Run and the analyses of ditch and stream waters downstream. At the time these samples were taken, the wastes from the weekly flushings were being discharged into the downstream ditch. Table 15 shows that the BOD of the water in the long ditch was 766 ppm and the BOD of Wilson Run below its point of discharge was in excess of 41 ppm. Inasmuch as local fishermen have reported finding dead fish in the stream after these Monday morning flushings, the organic load is apparently in excess of the assimilative capacity of the stream. Moreover, the waste in the ditch and the water in the stream had a black tarry appearance and a strong pyroligneous odor.

Recommendations

The pollution in Wilson Run which is attributable to the weekly discharge of concentrated wastes from flushing of the stills and vats can be readily abated without much cost to the Otto Chemical Company. We recommend that the company be ordered to carry out its promise to pump these weekly flushing wastes into the secondary lagoon where they may be disposed of by evaporation and leaching into the surrounding soil or by being drained gradually into the cooling-water ditch for discharge to Wilson Run. We have estimated the effect of proper lagooning and equalized discharge of these wastes upon the 5-day BOD and solids content of Wilson Run. The results of these studies are shown in Table 16 for uniform discharge of strong wastes during a period of 4 hours, 24 hours, 3 days, 5 days and 7 days. The table shows that the uniform discharge over a period of 3 days or longer will decrease the 5-day BOD in Wilson Run to loadings which

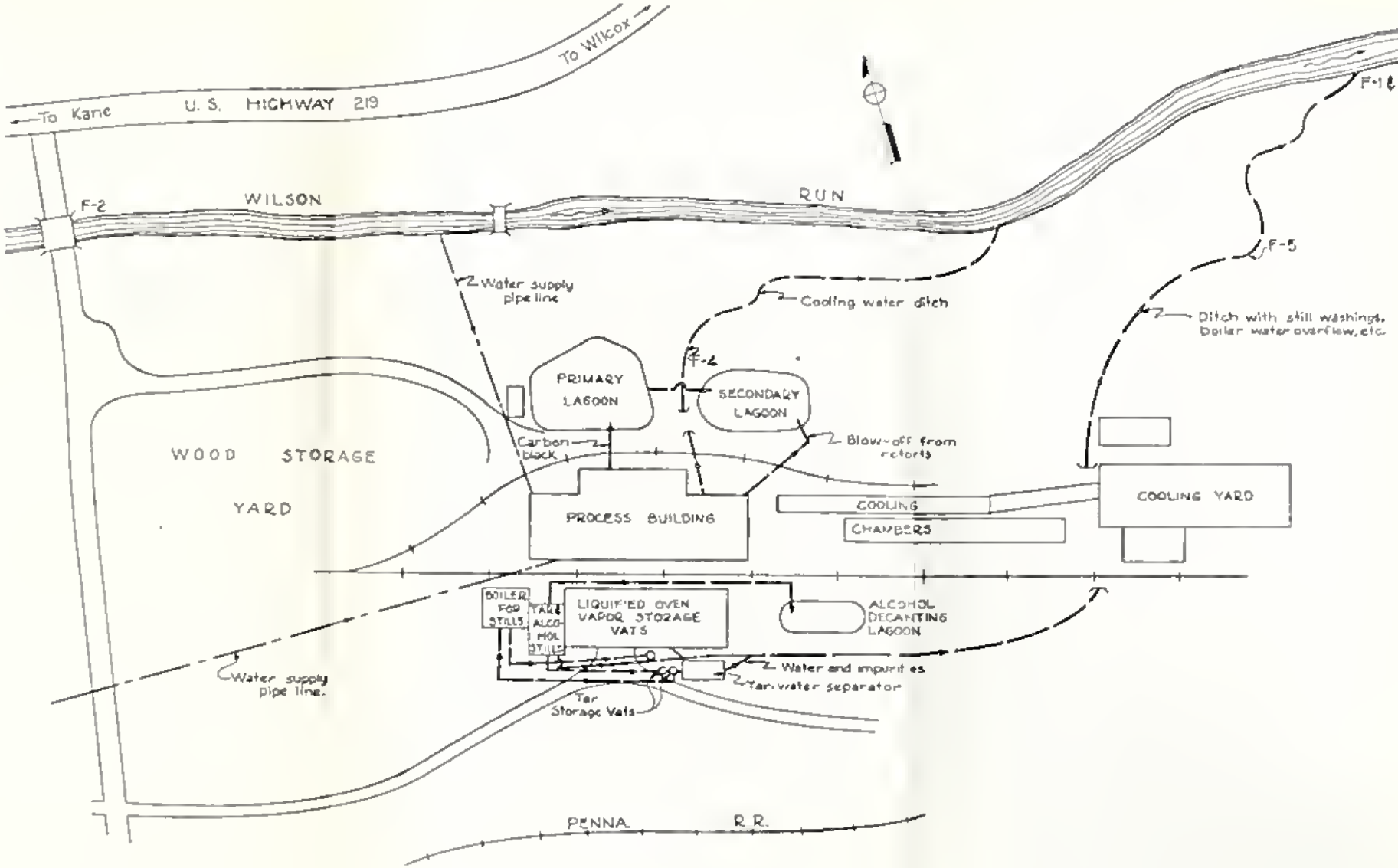

FIGURE 11. OTTO CHEMICAL CO. AT SERGEANT, PA., SKETCH OF DRAINAGE SYSTEMS.

TABLE 15. OTTO CHEMICAL COMPANY, SERGEANT, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED NOV. 1, 1948

Sampling Point	*Sample No.*	*Temp. ° C*	*5-Day 20°C B.O.D. ppm*	*Total Solids ppm*	*Suspended Solids ppm*	*Dissolved Solids ppm*	*Chlorides as Cl^- ppm*	*pH*	*Alkalinity to pH 4.3 as ppm of $CaCO_3$*
Wilson Run above Otto Chemical Co.....	F-2	7	1.8	142	6	136	35	7.67	65
	*F-1	8	over 6.4	199	32	167	42	7.28	74
Wilson Run below Otto Chemical Co.....	F-3	7	over 41	196	18	178	37	7.30	82
Cooling Water Ditch.....	F-4	24	22	185	13	172	51	7.63	70
Boiler Overflow and Wash Water Ditch..	F-5	22	766	502	104	398	24	5.68	100

* Sampled on October 29, 1948

can readily be assimilated by the stream. We have not estimated the cost of this recommendation inasmuch as it has already been planned by the company and represents a relatively minor expense.

The engineering and construction problems involved in the abatement of pollution at this mill are simple and should result in effective abatement if

TABLE 16. ESTIMATED EFFECT OF PROPER LAGOONING AND EQUALIZATION OF WASTES AT THE OTTO CHEMICAL COMPANY

Analysis	*Analysis of Strong Weekly Waste*	*Estimated Increase in Wilson Run at Drought Flow for Uniform Discharge of Strong Wastes During Period of*				
		4 hours	*24 Hours*	*3 days*	*5 days*	*7 days*
5-day B.O.D., in ppm.....	765	190	31.6	10.5	6.3	4.5
Total solids, in ppm.....	500	125	20.8	6.9	4.1	3.0
Suspended solids, in ppm..	100	25	4.2	1.4	0.8	0.6
Dissolved solids, in ppm..	400	100	16.6	5.5	3.3	2.4

the facilities are operated willingly and continuously. If the company does not cooperate by proper operation, effective abatement will require frequent policing by the Sanitary Water Board. In order to simplify enforcement of the Board's order, it is recommended that the facilities for pumping the flushing wastes into the secondary lagoon be constructed in such a manner as to prohibit the discharge of these wastes to any other place without expensive and time-consuming reconstruction.

VILLAGE OF SERGEANT

Description

There are approximately 15 houses of the village of Sergeant which are located along Route 219 near the Otto Chemical Company. Other houses are scattered along the road leading to Kane and on some side roads. There are no municipal sewers and each house has its own system of disposal. Some of these houses are reported to have private sewers discharging to Wilson Run. In view of the small drainage area and the consequent low drought flows, this direct discharge of sewage will cause bacterial pollution in excess of the allowable limit of 1,000 coliform organisms per 100 ml. The BOD of this small amount of sewage will not be of sufficient magnitude to effect the dissolved-oxygen content of Wilson Run.

Recommendations

We recommend that action be taken by the District Engineer or by local health authorities to order the owners of houses from which private sewers drain to Wilson Run to install sub-surface drainage systems.

CHAPTER V.

WEST BRANCH AT WILCOX

At Wilcox, where Wilson Run joins the West Branch of the Clarion River, the stream is subject to pollution from the Wilcox Tannery of the Keystone Tanning and Glue Company and from the village of Wilcox.

WILCOX TANNERY, KEYSTONE TANNING AND GLUE COMPANY

Description

Located on the east bank of the West Branch of the Clarion River about one-quarter mile below the junction of Wilson Run, the Wilcox Tannery of the Keystone Tanning and Glue Company manufactures sole leather by the vegetable tanning process. Between 150 and 175 persons are employed at the plant and work in two shifts, from about 3:00 AM to about 4:00 PM, for five days per week during normal operating conditions. Water is supplied from two wells on the property, and sanitary sewage at the tannery is discharged to the nearest drain. The mill uses approximately 33,430 lbs of raw hides per day and produces approximately 21,000 lbs of sole leather per day.

The industrial processes at this tannery are conventional for the vegetable tanning process and therefore will not be described in detail in this report. Liquid industrial wastes are produced from the raw hide soak (34,000 gpd), lime soak baths (12,000 gpd), water rinse (21,800 gpd), drippings from dehairing, fleshing and splitting, bate baths (45,000 gpd), tanning processes (10,250 gpd), and the scrub house (3,800 gpd). With the exception of the tan liquors, most of these wastes are highly alkaline and contain fleshings, hair, bits of hide, dung, sweat and blood. In addition to some of these animal wastes, the tan liquors contain pyrogallol or catechol tannins and other complex vegetable molecules.

Existing Methods of Waste Disposal

The present treatment facilities at the Wilcox Tannery comprise a main collecting sump and pump, mechanical flocculation, a primary settling basin, two secondary settling basins in parallel, an equalizing basin for uniform discharge of the final effluent, a long open sewer ditch, lagooning of sludge, and hauling of spent tan liquor to Ridgway for evaporation. The layout of these facilities is shown on Fig. 12. With the exception of the spent tan liquors and some of the drippings from the dehairing, beaming, fleshing, and splitting operations, all of the liquid industrial wastes are drained into a main collecting sump from which they are pumped by two 4-inch horizontal centrifugal pumps, each with a capacity of 330 gallons per minute (gpm) when operating alone, through a 6-in. steel force main to the flocculation chamber. During periods of normal operation, the daily production of liquid wastes is about 127,000 gallons, most of which is discharged in an 8-hour period at approximately 15,800 gallons per hour (312 gpm).

Although the wastes are produced from the intermittent emptying of the vats at an unequal rate, the main collecting sump tends to equalize flows to permit one pump to operate almost continuously.

The flocculation chamber is 10 ft by 20 ft in plan with a depth of about 10 ft. It provides a detention period of about 45 minutes with one pump in operation. The flocculated wastes then pass into a primary settling basin 52 ft long by 16 ft wide with an average depth of 12 ft, providing an overflow rate of 570 gpd per sq ft and a detention period of 3.78 hours with one pump in operation. The effluent from the primary settling basin is discharged to parallel secondary settling basins, each 105 ft long by 30 ft wide, with a volume of 125,000 gallons. The detention period in these basins is 12.6 hours with one pump operating and the overflow rate is 75.5 gpd per sq ft.

Liquid wastes are produced from about 6:30 AM to 2:30 PM each day, Monday through Friday. In order to distribute the discharge of each day's production of wastes over a 24-hour period, an equalizing basin has been provided with a length of 205 ft, a width of 30 ft and a depth of about 5 ft. The effluent from this basin is discharged continuously through an orifice box into an open sewer ditch which runs for approximately 3,000 ft parallel to the railroad track and empties into Oil Creek just upstream from the point where Oil Creek joins the West Branch. It is understood that this ditch had to be constructed because a right-of-way through the railroad property could not be obtained. While the use of this ditch represents a maintenance problem to the tannery, it also provides a supplementary degree of treatment in that the wastes flowing through the ditch are subject to aeration and the stabilizing action of biological slimes. This open sewer ditch also receives storm-water run-off and some sanitary sewage from private drains in the village of Wilcox.

Sludge from the primary settling basin is pumped by an 85-gpm plunger-type pump into the sludge lagoon and drying area. A small sludge lagoon adjacent to the treatment works is normally used for this purpose but ten additional acres of lagoon area are available between the railroad tracks and the river. To remove the sludge from the secondary settling basins, it is necessary to unwater a basin and scrape off the sludge by hand. Frequent removal of sludge is not required. Spent tan liquors are normally pumped from the tan vat into a tank truck and hauled to the evaporating plant at Ridgway (see Chapter VIII). When the Ridgway plant is unable to take some of the tan liquors, they are pumped to the spent-tan-liquor lagoon shown on Fig. 12. In the event that this lagoon becomes nearly full, provision has been made to decant the supernatant into the river. The tan-liquor lagoon has a capacity of approximately 2 million gallons (mg) at a 6 ft depth. It is understood that it is used only for a standby when the Ridgway tannery cannot take the tan liquors, and it is further understood that decanting from this lagoon has not occurred very often during the past several years.

Some of the drippings from the de-hairing, beaming, fleshing, flushing and splitting operations drain to an open ditch which originates in the village of Wilcox and carries storm drainage and some sanitary wastes from private sewers. These drippings are washed into the ditch at several points on the upstream side of the large railroad culvert and are carried through the

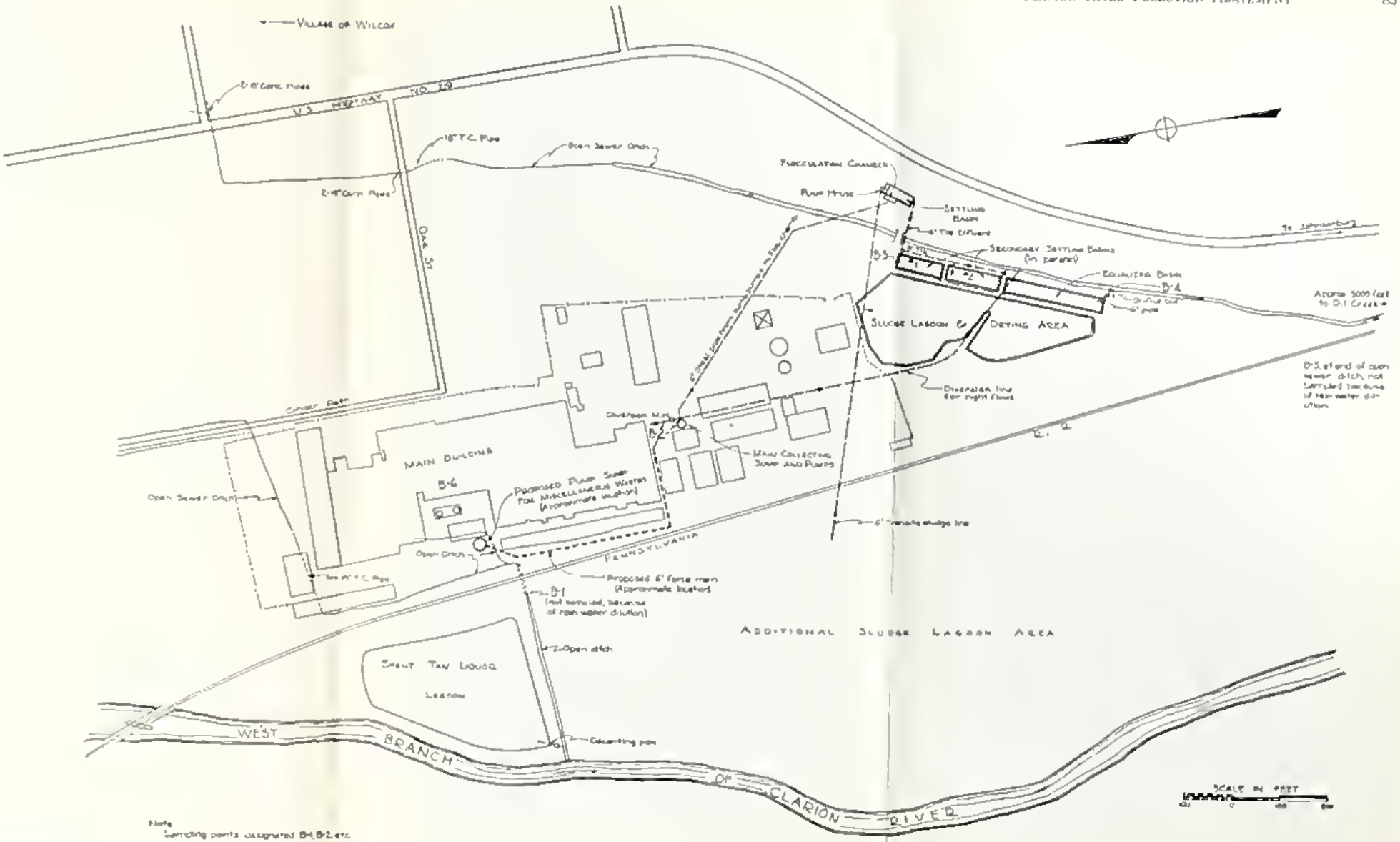

FIGURE 12. WILCOX TANNERY EXISTING WASTE DISPOSAL WORKS AND PROPOSED IMPROVEMENTS.

TABLE 17. WILCOX TANNERY, WILCOX, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED DECEMBER 21, 1948

Sampling Point	Sample No.	Continuous Time Discharge: From	To	Total Hours	Average Rate of Discharge: gpm	mgd	Total Daily Discharge mg	Temp. °C	5 Day, 20°C B.O.D.: ppm	lbs/day	SOLIDS: Total Solids: ppm	lbs/day	% Volatile	Suspended Solids: ppm	lbs/day	% Volatile	Dissolved Solids: ppm	lbs/day	% Volatile	pH	Alkalinity (+) or Acidity (−) to pH 4.50 as CaCO3: ppm	lbs/day	Total Sulfides as S**: ppm	lbs/day
Main Collecting Sump	B-2	6:00 AM	2:30 PM	8.5	186	0.2680	0.09465	10	892	703	11,179	8,814	83.5	3,304	2,605	24.6	7,875	6,210	1.5	11.50	+4,500	+3,550	26	20.5
Primary Settling Tank Effluent	B-3	6:30 AM	2:15 PM	7.75	165	0.2380	0.07680	10	519	332	7,393	4,730	4.5	1,872	1,200	31.0	5,521	3,530		11.65	+3,430	+2,195		
Reduction by Primary Sedimentation							0.01785			371		4,084			1,405			2,660				+1,353		
% Reduction							18.9%			52.8%		46.3%			53.9%			42.5%				38.2%		
Equalizing Lagoon Effluent at Orifice Box	B-4	6:00 AM	6:00 AM	24	53.3	0.0768	0.07680*	5.5	405	260	5,560	5,560	9.4	988	630	59.5	4,572	2,925		11.75	+2,175	+1,390	4.1	2.6
Reduction by Secondary Sedimentation (Without credit for equalization)										72		1,130			570			605				805		
% Reduction										21.7%		14.7%			47.5%			17.1%				36.7%		
Reduction by Secondary Sedimentation (With credit for equalization)										245		3,513			990			1,555				1,732		
% Reduction										73.8%		74.9%			62.5%			72.1%				78.9%		
Total Reduction by Treatment Plant (Without credit for equalization)										443		5,254			1,925			3,283				2,160		17.9
% Reduction										63.0%		59.6%			75.8%			52.9%				60.8%		87.4%
Total Reduction by Treatment Plant (With credit for equalization)										610		7,627			2,395			3,235				3,087		19.7
% Reduction										87.6%		86.5%			92 %			84.4%				87.0%		96.1%
Miscellaneous Drain through Culvert to River**	B-1						0.01371		96	11	1,720	195	54.8	157	18	93.6	1,563	180	50.9	6.5	+ 94	+ 11		
Spent Tan Liquor to Evaporation or Lagoon	B-6						0.01025	19	17,680	1,510	43,702	3,730	79.7	8,440	720	92.7	35,262	3,010	76 6	4 3	+ 325	+ 28		
Total Wastes Produced, During Working Day							0.11861		2,250	2,224	12,874	12,740		3,381	3,313		9,511	9,406			+3,634	+3,590	21	20.5
Total Wastes Discharged to River, during a 24-hr Day							0.09051		359	271	4,980	3,755		839	648		4,118	3,105			+1,858	+1,401	3.4	2.6
Total Reduction (Without credit for equalization)							0.02810			1,953		8,985			2,695			6,295				2,189		17.9
% Reduction										87.8%		70.5%			80.6%			67.0%				61.0%		87.8%
Total Reduction (With credit for equalization)										2,184		11,488			3,122			8,365				3,123		19.7
% Reduction										95.5%		90.1%			93.5%			89.0%				87.0%		96.1%

*Assumed equal to primary settling tank effluent. Actual measured flow was 0.032 mg. Difference went into increased storage in equalizing lagoon
**Sampled and analyzed from Pennsylvania Department of Health Survey, October, 1948.

culvert to an open ditch which discharges into the West Branch. It is estimated that the average volume of these wastes, which are discharged directly without treatment, is about 15,000 gallons in 8 hours or about 30 gpm if produced uniformly during the period.

Quantity and Strength of Wastes

A survey was made of the quantity and strength of industrial wastes produced at the Wilcox tannery on December 21, 1948. Attempts to obtain samples earlier had been thwarted by the fact that the tannery had suspended operations for several weeks. Operations were only resumed about 10 days before our samples were taken and for that reason this survey cannot be considered to be representative, inasmuch as at least a month is required for a tannery to attain normal operations. The points at which samples were taken are shown by numbers on Fig. 12. The results of the survey are presented in Table 17, which also shows the efficiency of the treatment works and various portions thereof.

At the time of our survey the total daily discharge from the main collecting sump was 94,650 gallons in 8.5 hours, as contrasted to a normal daily production of about 127,000 gallons. Sludge was pumped for 3½ hours during this period and amounted to 17,850 gallons. The actual measured average flow from the equalizing basin during an 8-hour period was at a rate of only 52,000 gpd, but this discrepancy can be accounted for by storage in the equalizing basin. During the early days of the week the water level in the equalizing basin rises as the basin is being filled, and during Saturday and Sunday this excess is drained off. Thus it can be seen that the equalizing basin serves not only to spread the 8-hour discharge over a 24-hour period, but it also equalizes the 5-day production over a 7-day period. For August, 1948, the company's records showed a maximum rate of discharge of 101,000 gpd, a minimum of 40,000 gpd and a 7-day average of 81,500 gpd, corresponding to 114,000 gpd on a 5-day basis.

Effectiveness of Treatment

The reduction of BOD on an 8-hour basis is shown by Table 17 to be 52.8% in the primary settling tank and 63.0% in the entire treatment plant. Considering the fact that the effluent is discharged more or less uniformly over a 24-hour period, the overall plant reduction of BOD on a 24-hour basis is 87.6%. When cognizance is taken of the total wastes produced at the plant including the spent tan liquors and the miscellaneous drain, as compared with the total wastes discharged to the river, Table 17 shows that the total overall reduction of BOD on a 24-hour basis is 95.5%, or on an 8-hour basis it is 87.8%. Even better efficiency is attained if we take into account the fact that the 5-day production of wastes is discharged more or less uniformly over a 7-day period. Corresponding figures are given in Table 17 for the reduction in total solids, suspended solids, dissolved solids, alkalinity and sulfides for each phase of the treatment processes.

Of particular interest is the last column in Table 17 showing the total sulfides. Approximately 100 lbs of sodium sulfide are used in the tannery each day, which is equivalent to 41 lbs per day expressed as sulfides. Of this amount 20.5 lbs appeared in the treatment plant influent and only 2.6 lbs per day remained in the treatment plant effluent, indicating an overall reduction in the tannery and treatment plant of 96.1% on a 24-hour basis. At

a pH of approximately 11.5 this sulfide content is not evolved as hydrogen sulfide (H_2S) gas, which accounts for the fact that no H_2S odor was noticeable at the tannery. Fortunately these sulfides are readily removed in the treatment works, primarily as a CaS precipitate in the sludge. Otherwise H_2S gas would be formed when the plant effluent is discharged into the West Branch where the pH value is near 7.

The appearance and odor of the wastes discharged into Oil Creek are characteristic of beam-house effluent to which some weak tan liquors have been added from the scrub house. They cause a slight reddish discoloration of Oil Creek for the short distance before it joins the West Branch, but there is no perceptible color or odor in the West Branch.

The industrial waste survey of the Wilcox Tannery indicates a high degree of removal of BOD, solids, alkalinity and sulfides, and our survey of the condition of the West Branch below Wilcox (see Chapter III) shows that the stream is not polluted with respect to these parameters. Furthermore it is known that the West Branch is regularly stocked with trout and is considered to be an excellent fishing stream. The bacterial analyses of the waters of the West Branch below Wilcox, as reported by the U.S.P.H.S. in 1940, indicate that the coliform concentration far exceeded 1000 per 100 ml for each of the three samples, and hence bacterial pollution from the tannery and village is still a problem.

The tannery uses about 3,000 lbs of lime per day, most of which eventually is discharged to the treatment works. This lime causes hardness in the treatment plant effluent, despite the fact that much of it is removed with the sludge. We determined the calcium concentration of the effluent to be 905 ppm as calcium, which is equivalent to 1,370 lbs per day as lime, or 2,450 lbs per day as $CaCO_3$, indicating that about 46% of the calcium used appeared in the effluent. According to the U.S.P.H.S. analyses of 1940, the average hardness in the West Branch at Rolfe was 80.7 ppm at an average flow of 21.7 cfs and the average hardness of the East Branch at Johnsonburg was 54.3 ppm at an average flow of 38.7 cfs, a difference of 26.4 ppm between the two branches. Deducting 2,450 lbs. per day of hardness for the tannery we computed that the resulting hardness in the West Branch in 1940 would have been 61.0 ppm, which is quite comparable to the 54.3 ppm observed for the East Branch. The increase in hardness in the West Branch attributable to the tannery was thus seen to be about 20 ppm when the average flow was 0.23 cfs per sq mi. For drought flow (0.10 cfs per sq mi) it might be expected that the tannery discharge would increase the hardness about 46 ppm.

The paper company at Johnsonburg uses river water from the East Branch and West Branch, supplemented by well water during periods of low flow. In the dry months of the year the paper company is troubled by hardness in the process water and it has been felt that much of this hardness was attributable to the tannery wastes at Wilcox. While the paper company did not have analyses of each source of water in the wet months and dry months, it did have a record which shows that the hardness in its water treatment plant effluent in April, 1948, was 12.0 ppm as $CaCO_3$ and in September, 1948, it was 195.0 ppm, an increase of 183 ppm. Assuming that the stream flow was 0.23 cfs per sq mi at that time and that 40% of the water was taken by the company from the West Branch, we estimate that not

more than 8 ppm of this 183 ppm increase was attributable to the tannery. The remaining increase in hardness can be charged against the high proportion of well water which must be used during dry months. When the East Branch dam is completed and the stream flow at Johnsonburg is maintained at 87 cfs or higher adequate surface water will always be available and the paper company should not have to resort to its wells, thus solving the problem of hardness in the water. In any event, however, our figures show rather conclusively that very little of the increase in hardness at the paper mill can be attributed to the Wilcox Tannery. We conclude therefore that this slight increase in hardness does not constitute pollution.

Recommendations

Although the treatment plant is functioning effectively to remove BOD, solids, alkalinity and sulfides, there are several problems of waste disposal at the Wilcox Tannery which deserve special consideration and discussion, as described below.

The disposal of sanitary sewage at the Wilcox Tannery poses a special problem inasmuch as all sewage now mixes with the industrial wastes. Wattie and Chambers (Journal of the American Water Works Association, June, 1943) studied the death rates of coliform organisms at various pH ranges and found that a complete kill was obtained in four hours at pH 11.0 to 11.5 and in 10 hours at pH 10.5 to 11.0. With typhoid bacteria, the kill was even faster. Inasmuch as the total detention period in the tanks and lagoons of the treatment works is over 48 hours and the pH of the influent and effluent is above 11.0, effective destruction of coliform organisms and intestinal pathogens should be attained. We recommend, therefore, that the existing method of disposal of sanitary sewage be continued, subject to the improvements described below.

The main volume of liquid wastes produced at the tannery is discharged between 6:00 AM and 2:30 PM, and during the remaining hours of the day the only wastes are those from sanitary fixtures and floor drippings. It is the present practice to change the valves at the diversion manhole shortly after 2:30 each day and to allow the sewage and drippings to be discharged directly to the open ditch which normally receives the treatment plant effluent. Consequently some raw sewage is discharged to the ditch without benefit of primary settling or a long period of contact with wastes of high pH. We recommend, therefore, that this procedure of diverting the wastes for 16 hours each day be discontinued and that all wastes be discharged into the main collecting sump and pumped through the treatment plant. This does not mean that the flocculating and sludge-scraping mechanisms at the treatment works need to be operated except during the conventional 8-hour period, but it does mean that the pump at the main collecting sump must be operated automatically for the entire day or else operated intermittently by manual control for a few short periods each night.

Another special problem at the Wilcox Tannery pertains to the two open ditches which traverse the property (see Fig. 12). Each of these ditches carries storm-water run-off from tannery property and also from parts of the village of Wilcox. They also are reported to receive sanitary sewage from certain private sewers in the village. The open ditch which passes near the main process building also receives wastes from the de-hairing, beaming, fleshing, flushing, and splitting operations. Although they do not constitute a

great volume of water, the drippings from these operations contain obnoxious solids which should not be drained to the stream. We recommend, therefore, that these industrial wastes be collected in a separate sump and pumped to the main collecting sump as shown in Fig. 17.

We recommend that the new collecting sump be constructed approximately at the location shown in Fig. 12. This sump should be about 10 ft deep with an area not less than 4 ft by 5 ft. Duplicate 150-gpm horizontal centrifugal pumps should be located in a dry well adjacent to the sump and should discharge into a 6-in. force main conveying the wastes to the main collecting sump. Each of the pumps should be capable of handling the entire anticipated load with intermittent operation. We estimate that the entire installation, including catch basins to collect the wastes, free-flowing sewers to discharge the wastes into the collecting sump, the entire structure and equipment at the sump location and the 6-in. force main, will cost about $11,000. We furthermore recommend that the diversion manhole be reconstructed in such a manner as to cause all wastes to be discharged at all times into the main collecting sump and that an overflow weir be built into this manhole to allow the wastes to overflow into the diversion line only when the pumps fail to operate and the wastes accumulate in the collecting sump to the overflow elevation. When these recommendations are put into effect all sewage and industrial wastes at the Wilcox Tannery will be subjected to treatment by the existing treatment plant.

The outlet device from the equalizing basin is intended to provide discharge to the stream at a continuous uniform rate over 24 hours of the wastes produced during the working shift, but the design of the orifice box permits the discharge rate to vary with the head on the orifices. For example, during August, 1948, the average 24-hour rate of discharge varied from 40,000 to 101,000 gpd and the hourly rate varied over an even wider range. It is a simple matter to remedy this defect so as to provide a constant rate of discharge for a month or more at a time. To this end we recommend that the orifice box be remodelled to provide for discharge through a single constant-head orifice. A throttling valve may be used for the orifice so as to regulate the rate of flow.

VILLAGE OF WILCOX

Description & Recommendations

There is no municipal sanitary sewage system for the village of Wilcox, but many private sewers are reported to drain into storm-water ditches which discharge into the West Branch. In view of the fact that the village has a population of only about 1,000 persons and the houses are scattered, it seems unlikely that a municipal sewer system will be installed in the near future. We recommend, therefore, that the Pennsylvania Department of Health check the method of disposal from each house, and that the Sanitary Water Board prohibit the discharge of any putrescible wastes to the storm-water ditches. Properly constructed sub-surface drainage systems should suffice for this community until it becomes advisable to build municipal sewers and treatment works.

CHAPTER VI.

CLARION RIVER AT JOHNSONBURG

At the confluence of its East and West Branches at Johnsonburg, the Clarion River becomes grossly polluted by industrial wastes from the pulp and paper mill of the New York and Pennsylvania Company. It also receives the sanitary sewage from the mill and from the borough of Johnsonburg. Another potential source of pollution at Johnsonburg is the aluminum-sulphate plant of the General Chemical Division of the Allied Chemical and Dye Corporation. Each of these potential sources of pollution is discussed in this chapter.

NEW YORK AND PENNSYLVANIA COMPANY

Description of Plant

A location plan of the New York and Pennsylvania Company's pulp and paper mill is shown by Fig. 13. The mill employs about 1,200 persons and has operated 24 hours a day, seven days a week, for the past five years or more. The entire plant comprises a soda mill, a sulfite mill, an old-paper department, a paper mill, a bleach plant, a power plant, a water filtration plant and many auxiliary plants. Each of the important parts of the works is described below. The water supply for industrial purposes is taken from the East and West Branches and from numerous wells which are used during dry seasons. Almost all of this process water is returned, directly or indirectly, to the Clarion River within a few miles of Johnsonburg. The sanitary sewage at the mill is discharged into the nearest ditch and mixes with the industrial wastes.

Pulping & Paper Making

The water for the pulping and paper-making processes which is filtered at the rapid sand filtration plant on the East Branch is taken from several sources: the East Branch, a tributary of the East Branch, 37 air-lift wells adjacent to the East Branch, the West Branch, 60 air-lift wells along Silver Creek (a tributary of West Branch) and deep wells near the filter plant. Well water is only used during dry months when the surface run-off is inadequate. In addition to the process water which passes through the filtration plant, there are other sources of water which are used without treatment or are treated separately, as follows: river water from the East Branch which is pumped directly to condensers and returned to the stream without treatment, water from two deep wells near the sulfite mill which is used without treatment for acid production and pit washing, and boiler feed water which is obtained from the river and treated by separate filters. The average daily quantity of water treated at the main filtration plant in 1947 was 20.5 mg of which 15.0 mg came from the East Branch, its tributary and its wells. In general, water is consumed at a fairly uniform rate. The foregoing data regarding the average water production are useful in providing a check on the quantity of waste water produced.

Liquid wastes are produced from waste wash water and sludge at the water treatment plant (D-18) and from the cooling waters used at the

power plant (D-15). During periods of low flow in the East Branch, when the main filter plant takes all of the flow, this cooling water is re-used many times with a resulting temperature reported to be as high as 120°F in the pool behind the low dam.

The Soda Mill

The soda mill was in the process of being rehabilitated at the time of our survey, and inasmuch as our samples were taken with the old system we shall describe it as well as the new one which is now in operation. All of the details of the industrial processes in the soda mill will not be described herein, but only those which relate to the production of important liquid industrial wastes. The soda mill had a total output of 125 tons of air-dried pulp per day as of October, 1948. There are now 16 digesters and one chip reboiler which are operated at the rate of about 50 blow-downs per day.

With the old system, the digesters were blown into an old blow tank, the contents of which were then rinsed by black liquor into eight brown-stock pans. The initial drainage of black liquor was drawn to a storage tank and the brown stock was then washed with hot water. The first washes were also drained to the storage tank until the specific gravity of the liquors became too low, after which the wash waters were drained to the so-called alkali ditch (D-6 on Fig. 13). After being washed in the brown-stock pans, the soda pulp was drained to a stock tank in the basement and later pumped to the subsequent washing operations. The strong-black-liquor storage tank, which received the initial drainage from the brown-stock pans and the strong rinse waters, was of insufficient capacity and frequently overflowed to the alkali ditch. Strong black liquor from this storage tank was processed as described hereinafter for soda recovery.

To replace the brown-stock pans and the batch process of washing, the Company has recently installed an Impco counter-current washer comprising three vacuum filters in series, similar to that shown diagrammatically in Fig. 14. From a new blow tank, the digested pulp and strong black liquors are pumped to the Impco washer and subjected to a counter-current flow of rinse waters in a closed system. Washed stock issues from one end of the machine and strong black liquor from the other end.

After its initial washing in either the old brown-stock pans or the new Impco washer, the stock is then subjected to further washing and processing through de-knotters, centrifugal screens, and wire cylinder washers. Much of the water used in this processing is recirculated but there is an overflow from the brown-stock-thickener wash-water tank. It is understood that this screening and washing equipment is being continued in use even with the new Impco washer but any overflow from the brown-stock-thickener wash-water tank should be much weaker with the new Impco washer in service. It has been estimated by the manufacturer that 98% of the BOD produced in the soda process will be removed by the Impco washer in the form of strong black liquor which is subjected to soda recovery.

The bleaching operation in the soda mill is carried out without any liquid wastes, but following bleaching the white stock passes through three cylindrical white-stock thickeners, the effluent from which is partially recirculated, partially used as beater water and partially sent to the central white-water tank, from which there is an overflow to the white-water ditch (see later discussion of paper mill).

The soda recovery system comprises: (a) a quadruple-effect system of

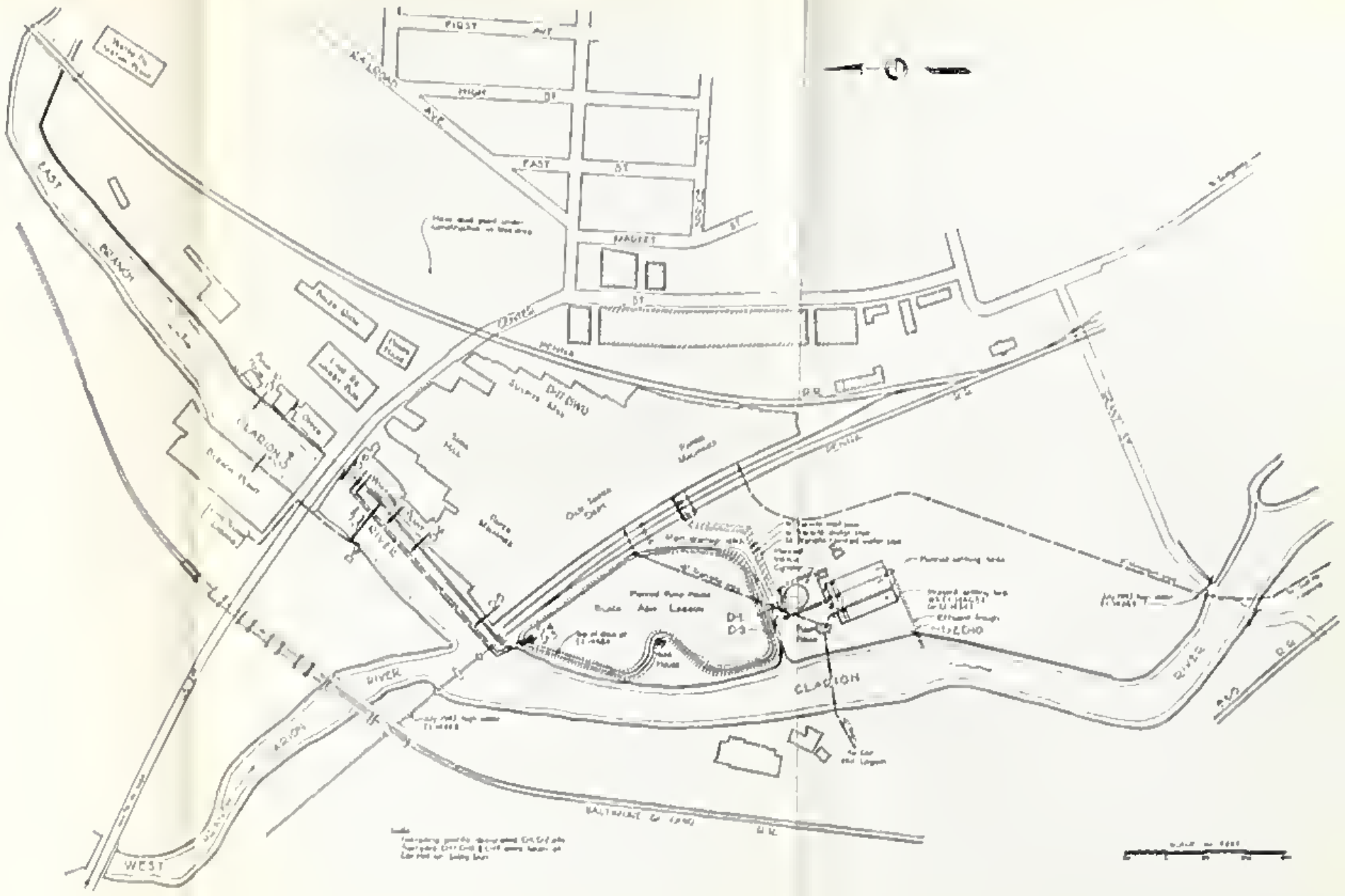

FIGURE 13 NEW YORK AND PENNSYLVANIA COMPANY EXISTING WASTE DISPOSAL WORKS

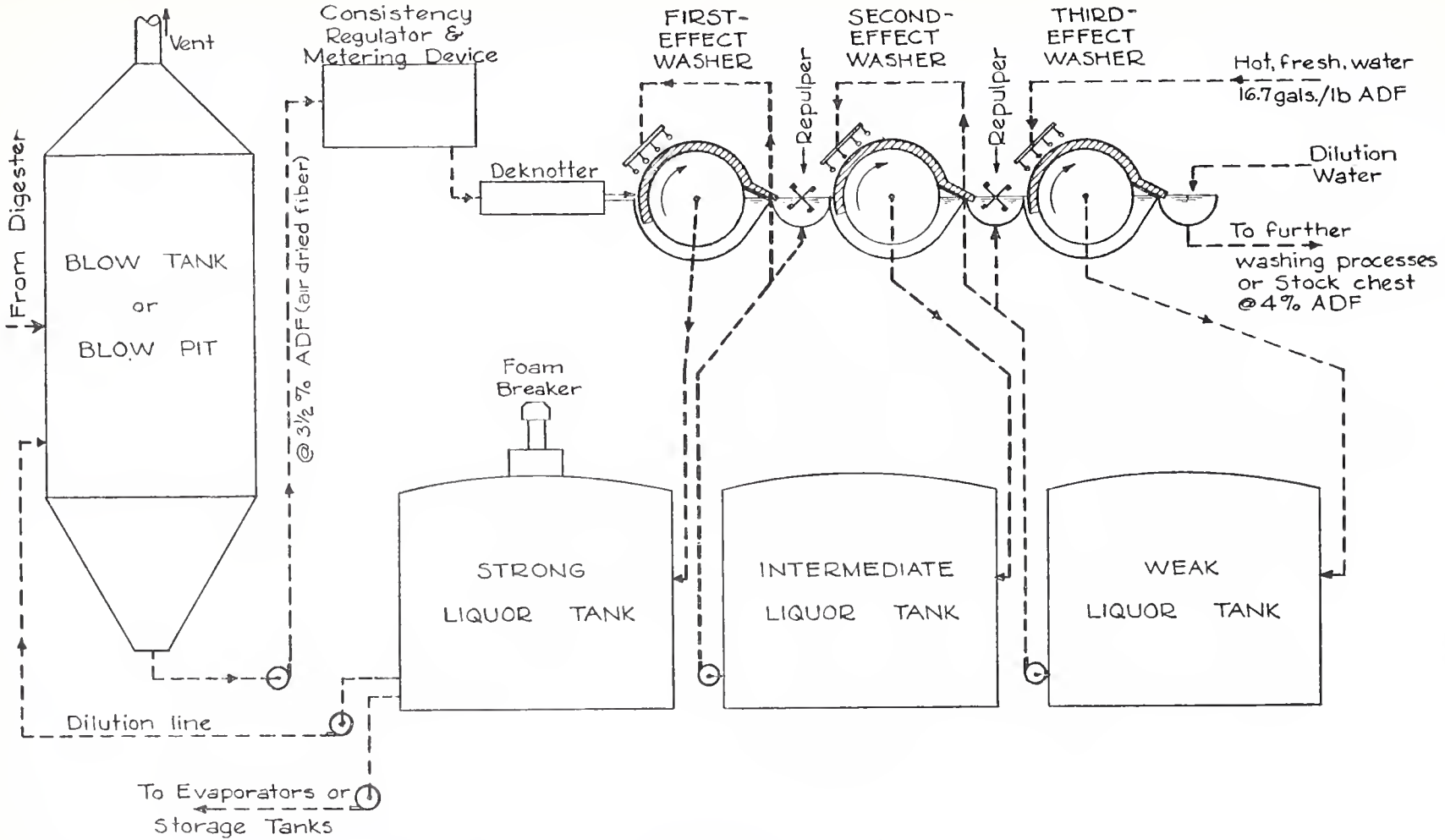

FIGURE 14.

DIAGRAMMATIC SKETCH OF A TYPICAL COUNTER-CURRENT WASHER

Swenson evaporators which thicken the strong black liquor for subsequent operations, (b) a Greenewalt furnace which receives part of the tarry liquid from the evaporators and converts it into molten sodium carbonate, (c) old rotary furnaces which take the remainder of the residue from the evaporators, (d) the green-liquor leaching plant, (e) the recausticizing plant for converting sodium carbonate to sodium hydroxide and (f) the whiting plant for recovery and processing of calcium carbonate which can be used for filler. Condensate from the Swenson evaporators passes through a barometric seal and is discharged to the East Branch (D-8). This drain also receives surface run-off from the yard and street. Leakage and the clean-up water from this process drain into the alkali ditch (D-6). There is no liquid waste from the Greenewalt furnace although cooling water from the shell is discharged to the stream.

The old rotary furnaces which are fired with coal and sawdust serve to burn off most of the organic material in the tarry residue. The product of this operation is then leached by a counter-current flow, the effluent which contains dissolved sodium carbonate being sent to the recausticizing plant and the carbon being piped to the black-ash basin (D-3, see description of treatment works). The recausticizing plant has no direct liquid waste; but the whiting plant discharges granular calcium carbonate in a water slurry, most of which is piped to the black-ash basin (D-4), but some is discharged to the East Branch (D-7). The whiting wastes were formerly pumped to Dill Hill lagoon along with the old-paper waste, but the calcium carbonate quickly clogged the pipe line. It has been reported that the new whiting plant, soon to be built, will produce no liquid wastes.

The Sulfite Mill

The sulfite mill produces approximately 95 tons per day of long-fibered sulfite pulp, some of which is shipped as lap stock to the Lock Haven mill of the same Company. The acid for the sulfite digesters is produced by burning sulfur and passing the SO_2 fumes through Jenssen towers for reaction with limestone to form calcium bisulfite cooking liquor. Cooling water from the Jenssen towers, containing some entrapped SO_2 is discharged to the main sulfite ditch. A new acid plant now under construction (see Fig. 13) will eliminate the Jenssen towers and produce calcium bisulfite cooking liquor by the passing of SO_2 fumes through a slurry of $Ca(OH)_2$.

The four large sulfite digesters are each used about three times per day and discharge into four blow pits where the strong sulfite waste liquor (SWL) is drained off and pumped into SWL storage tanks. The washing procedure in the blow pits was altered during the course of our survey, the modified procedure being installed late in October, 1948. Under the previous method, the drained pulp in the blow pits was washed with white water or clear water, with all wash liquor being discharged to the main sulfite ditch. With the new procedure, however, the drained pulp is first washed with weak SWL and the effluent is pumped to the strong SWL tank. Then the pulp is washed with clear water and the effluent is sent to a weak SWL storage tank until the specific gravity drops to 1.5° Baumé, after which the effluent is ditched (see Fig. 15). In effect, this procedure constitutes a batch counter-current wash, which we shall discuss in considerable detail later in this chapter inasmuch as this phase of the sulfite process constitutes the principal source of organic pollution in the river.

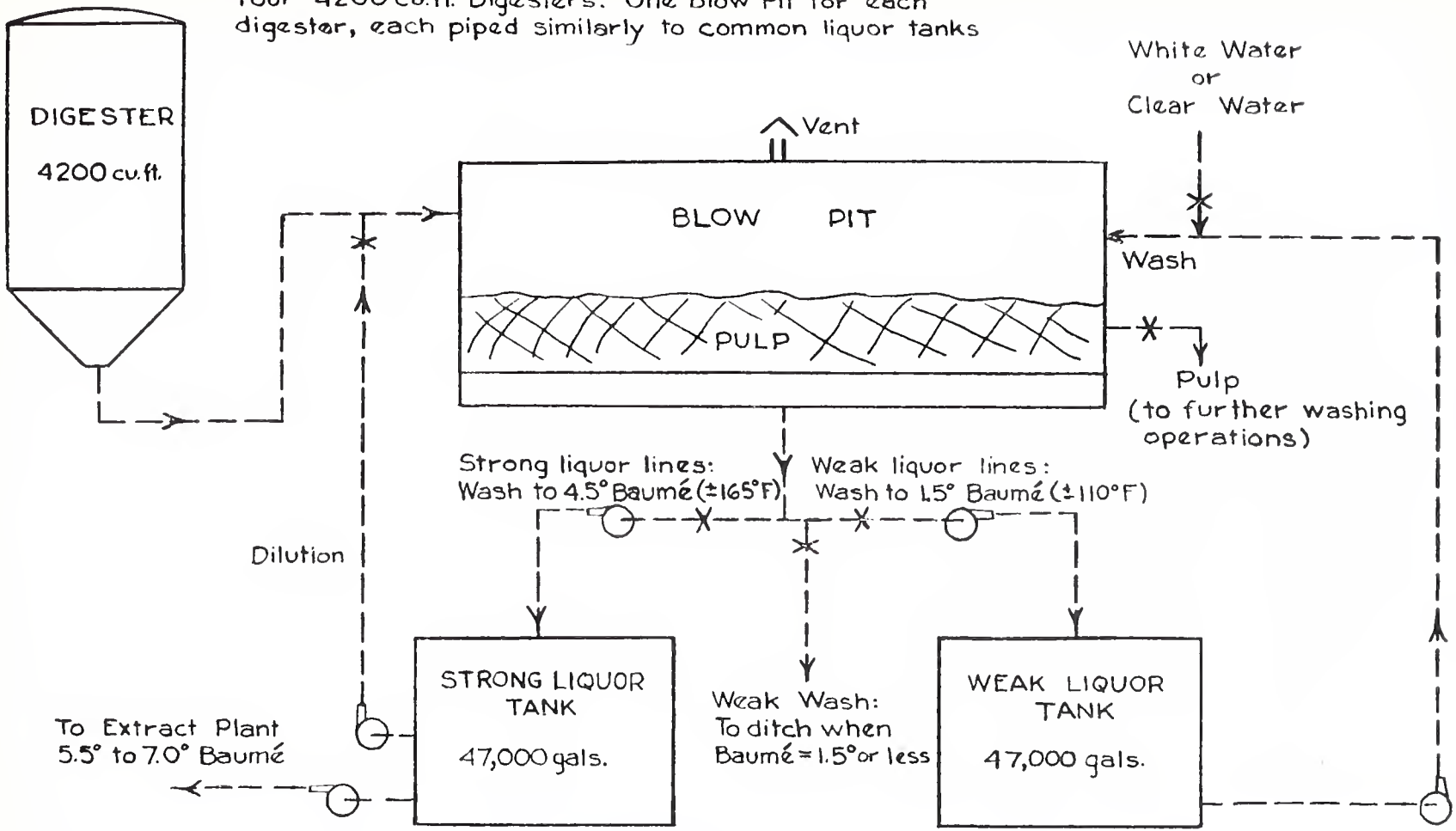

FIGURE 15.
DIAGRAMMATIC SKETCH OF DISPLACEMENT WASHING SYSTEM

The washed sulfite stock is then pushed by high pressure hose to the raw-stock tank from whence it is pumped to an Oliver washer, diluted with white water and then filtered. The filtrate, about 1.68 mgd, is discharged through a seal-pit to the main ditch and the filtered stock is then subjected to further screening and washing. The only major source of waste from the subsequent washing operations is the effluent from duplicate Oliver thickeners, some of which is used in the blow pits, on the flat screens, and on the Oliver washer, and the remainder of which, about 3.45 mgd, goes to waste in the main ditch by way of a seal-pit.

Following the screening and washing, the stock is bleached (no waste) and then run onto Rogers machines which are modified paper machines producing a lap stock suitable for shipment. Cylinder and tray water from the Rogers machines goes to a save-all from which the clarified effluent is discharged to the main ditch. Water from the press rolls is ditched directly because it contains fine felt fibers and cannot be re-used.

Strong SWL from the blow pits is filtered to remove coarse solids and is then sent to the extract plant where it is concentrated by evaporation and shipped away in tank cars as Clarion Extract. The pipeline through which the concentrated liquor flows into tank cars has a connection draining into the main ditch. Prior to evaporation, the pH of the strong SWL is adjusted to near neutral and the liquor is passed through filter presses which remove the calcium monosulfite which has formed in the process. The calcium monosulfite filter cake (about 6 to 8 tons per day) was once hauled away and dumped, but more recently it has been slurried to the Dill Hill pump station and pumped to the Dill Hill lagoon. At times the filter presses leak onto the floor and, with other floor drainage, this leakage constitutes an important and erratic source of organic pollution. Another organic waste from the extract plant is the condensate from the multiple-effect evaporators, which is discharged to the main ditch. When the evaporators are cleaned, the clean-out wastes also go to the main ditch.

The main ditch which traverses the sulfite mill originates as a storm drain of the borough of Johnsonburg. At the sulfite mill it receives Jenssen tower cooling water, condensate, floor drainage and clean-out wastes from the extract plant, concentrated Clarion Extract from the pipeline drainage, wear SWL from the blow pits, Oliver washer water, Oliver thickener effluent, Rogers machine save-all effluent and the press-roll water. The main ditch also receives waste from other mills and departments, as described hereinafter. The ditch has a dry-weather flow of about 12 mgd, or about 60% of the total water consumption of the entire mill.

Old-Paper Processing

The old-paper department produces about 50 tons per day of pulp from over 120,000 lbs per day of magazines, baled paper, broke, roll trim, and rejects from publishers. Printed material (about 66,000 lbs per day) is passed through four dusters which shred the magazines and knock out hinges, pine and bindings. Dry wastes from the dusters are dumped once a day to the main sulfite ditch. The shredded paper passes next to four open soakers where it is subjected to raw caustic, return caustic and heat (but not to pressure). The stock is scraped up on an incline, from which caustic solution drains back into the soakers, and is then placed in seasoning pans. Overflow from the soakers passes to the return-caustic tank from which it can be re-used. This tank overflows frequently to the main ditch. The

soakers are cleaned out periodically and the drainage therefrom goes to a catch-all tank which retains the stock and muck, while the effluent is discharged to the Dill Hill sump. The stock and muck so recovered are then discharged to the main ditch. Apparently the purpose of the catch-all tank is to preclude clogging of the Dill Hill pumps or pipeline. It is understood that the Company has decided to replace all of the above described process with a Hydropulper which will eliminate the dust, caustic overflow and catch-all wastes.

Trim and rejects (40,000 lbs per day), which are only semi-inked, pass through shaving hogs where water, steam and caustic are added. The soakers are by-passed and the stock goes directly to the seasoning pans. The broke or roll trim is fed through a separate hog and treated with steam and water only, then goes to the fourth bleacher (see below).

Stock from the soakers and shaving hogs passes to six seasoning tanks where it stands for about 48 hours, with caustic being drained to the return caustic tank. Leakage and clean-up wastes from the seasoning tanks go to the main ditch but such wastes are intermittent and minor in importance. From the seasoning tanks the stock is hosed into beaters (no waste) and then is pumped to the riffles tank where pins, binders, strings, etc. are removed. Settled material from the riffles is fished out and hauled away by dump truck.

The effluent from the riffles tank passes to duplicate flat screens where it is sprayed with return water from the Lancaster washers (see below). Tailings from these screens, amounting to about 5% of the incoming stock slurried in 200,000 gpd of water, are discharged to the main ditch. The accepted stock flows into nine Lancaster washers, arranged in series in groups of three. In effect, these three groups of washers in series constitute a continuous counter-current washing system similar in principal to the new Impco washer in the soda mill. The effluent from the first group of cylinders (about 1.5 mgd) goes partly to the head box of the flat screens and mostly to the Dill Hill pumps. It constitutes the principal source of waste from the old-paper department. The effluent from the second and third group of cylinders goes to a wash-water tank from whence it is pumped to showers on the first group of cylinders, to the flat screens, to the riffles, to the seasoning tanks, or to the drainers (described below). This wash-water tank, in hydrostatic balance with the central white-water tank, has considerable overflow which discharges to the machine-shop sump and out the white-water ditch (D-5).

From the third group of Lancaster washers the stock is pumped to four bleachers in series (no waste) and then to the drainers, which now act primarily as storage units. They were originally planned to drain off some of the bleach water through porous underdrains but that system is now blocked. Instead the tanks leak and drip through the wooden sides and this continuous leakage, plus any overflow that may occur, drains to the machine-shop sump and out the white-water drain (D-5).

The rejected effluent from the first group of Lancaster cylinders normally flows to the Dill Hill pump house, but whenever the Dill Hill pumps are out of operation or whenever the flow exceeds the capacity of the pumps the excess flow passes through a concrete conduit to the main sulfite ditch. The same method of overflow applies to the filter cake from the extract plant which normally goes to the Dill Hill pumps. This by-pass, which op-

erates frequently, constitutes an unpredictable upsetting influence on the main drain wastes inasmuch as such overflows have marked effect upon the pH and other characteristics.

Pulp from the sulfite, soda and old-paper mills comes together for the first time in the beater room, the soda and old-paper stock entering through pipes and the sulfite pulp being carted in as lap stock. Soda and old-paper stock are added to the beaters and mixed. Then the revolving washer is dropped into the pulp and a few inches of water are washed to the drain. Sulfite pulp is then added and beaten into the mixture. The revolving washers then drain off 10-in. of water after which fillers and dyes are added. drain (D-5).

There are 14 beaters of which four wash to the main ditch and 10 to the white-water drain. The beater drainage represents water from well-washed stock and hence is not likely to contain much polluting substance. From the beaters the contents are dropped to six stock chests. There is no regular drainage from the stock chests, but periodic wash-downs drain either to the main ditch or to the white-water ditch, depending on which stock chest is being cleaned.

Each of the eight paper machines at this mill differs somewhat from the others insofar as waste waters are involved. In general, most of the tray water and suction-box water is returned to the head box, the remainder passing to save-alls. Wire water goes to a central wire-water box or to an auxiliary wire-water box from which some of it is pumped to the old-paper department; but most of it overflows to the white-water ditch.

Save-alls are used for all of the paper machines and reduce the fiber in the white water from about 2,400 ppm to about 140 ppm. Some of the effluent from these save-alls is pumped to a central white-water tank from which it is used in the soda mill, old-paper department and the beater room. Overflow from the central white-water tank, as well as the remaining save-all effluent, discharges to the machine-shop sump and out the white-water drain (D-5).

The #5 and #6 machines have a separate save-all, the effluent from which is passed through a Laughlin filter and then used as shower water on the #1 machine. Sludge and waste water from the Laughlin filter is discharged to the main ditch. Hence the Laughlin filter acts not as a means to produce pollution but merely as an internal mill process to give clearer shower water.

While much of the white water is discharged from the white-water ditch (D-5), more than 4.0 mgd of it is pumped from the machine-shop sump to a steam turbine where it is used to condense steam and to retain the seal on a barometric leg. Following this use it is rejected to the main sulfite ditch.

The Bleach Plant

The bleach plant produces caustic soda and calcium hypochlorite from the electrolytic decomposition of sodium chloride and the blending of chlorine gas with a lime slurry. Cooling water from the caustic cooling vats and the cooling of chlorine gas is discharged to the East Branch (D-14). The spent lime slurry, containing considerable $CaOCl$, is cleaned from the liming towers once each day to two lagoons and settled to remove solids. The supernatant from the lagoons is siphoned for four to eight hours each

day into the East Branch and the sludge is hauled periodically to a dumping area located on the opposite bank of the Clarion River.

Quantities and Strengths of Wastes

The various wastes described above discharge to the East Branch or to the Clarion River through the ditches and drains shown on Fig. 13. During the course of our survey we sampled each of the principal outlets, except D-18, at least once and in the case of the main ditch, several times. The results of the preliminary industrial wastes survey are presented in Table 18. These analyses and flows have been studied in conjunction with data obtained by the Company and by the Department of Health, and the combined results lead to the following observations.

The main ditch receives wastes from the sulfite mill (as summarized hereinbefore), tailings from the flat screens in the old-paper department, white water used in the steam condenser, backwash from the Laughlin filter, some beater water, intermittent overflow from the return-caustic tank, duster clean-outs, occasional overflows from the Dill Hill system, minor floor drainage, sanitary sewage from the mill and storm-water run-off from the borough. The sulfite mill and steam condenser water account for over nine-tenths of the total dry-weather flow in the ditch.

Our gaging and sampling test of October 22, 1948, was conducted at a time when the modified displacement washing method in the sulfite blow pits was not in operation. During that 8-hour period, the average flow in the main ditch as measured at a 12-ft weir with an allowance for the quantity pumped through the settling tank, was 12.3 mgd and the 5-day BOD (20°C) was 402 ppm, indicating a total BOD load on a 24-hour basis of 41,200 lbs per day. We have tabulated the results of past tests by others under comparable conditions and have found an average value of 36,100 lbs per day, a maximum of 47,600 lbs per day and a minimum of 25,400 lbs per day, indicating that our results were in line with other tests.

After the modified displacement washing system was placed in operation, several BOD analyses of main-ditch wastes were made by the Company, Department of Health and our engineers. The maximum of these tests was 41,400, the minimum 13,700 and the average 24,600 lbs of 5-day BOD per day, which is 11,500 lbs per day less than the average prior to such operation. It appears, therefore, that the present system of displacement washing of sulfite pulp has reduced the BOD load in the main ditch by about one-third.

Inasmuch as Table 18 shows that about 90% of the BOD load discharged to the river emanated from the main ditch, we decided to investigate its major component wastes. A preliminary survey indicated that most of these wastes were relatively uniform in flow and strength, but that the weak SWL changed markedly from hour to hour depending upon the operation of the blow pits. For that reason we conducted a continuous 72-hour test, gaging and sampling the weak SWL very 30 minutes and the other major wastes every hour. For comparison we also sampled and gaged the entire flow in the main ditch. No attempt was made to gage or sample the minor sources of waste or the unpredictable overflows from certain tanks. The weak SWL was gaged at a special weir box installed by the Company for use with a DeZurik sampler, but at the time of these tests the DeZurik sampler was not in place. The modified displacement washing system was being used in the blow pit at the time of this test.

The results of the 72-hour test are presented in Table 19 and show that the major sources of BOD in the main ditch are the weak SWL, the Oliver washer, the Oliver thickeners and the steam condenser water. The gaged wastes account for 82.7% of the BOD in the main ditch, indicating that the miscellaneous overflows, Laughlin filter backwash, old-paper tailings and floor drains contribute an appreciable load. It is also significant to note that during the third and fourth 8-hour gaging periods there was considerable leakage from the pans under the filter presses in the extract plant, enough, in fact, to cause heavy foaming in the drains and ditches and to preclude proper sampling. This leakage of strong SWL resulted in a high BOD in the total flow of the main ditch, with an excess of 14,570 lbs per day over the average of the other sampling periods. That such leakage occurred during the course of this test was not entirely unfortunate, for it pointed clearly to one of the principal difficulties with any program of pollution abatement, namely, that each treatment process must be fool-proof or be provided with alternate emergency means of satisfactory disposal.

The second largest contributor of BOD to the river, as indicated by Table 18, was the soda-mill alkali ditch, (D-6). This ditch was gaged and sampled on October 22, along with other points of discharge; but the BOD was not determined because sufficient dilutions were not made. The BOD value was something in excess of 708 ppm (3,830 lbs per day). The samplings and analyses were repeated on November 2 and yielded a BOD value of 351 ppm (1,900 lbs per day). The inconsistency of analyses of the effluent of this ditch is attributable to the intermittent overflow from the strong-black-liquor tank. Now that the new Impco washer is in service and new black-liquor storage tanks are available, the pollutional load from the alkali ditch should be very low (see our recommendation with respect to this ditch, presented hereinafter).

The white-water waste channel receives a great variety of wastes, principally overflow from the central white-water tank, beater water, overflow from the wire-water tank and overflow from tanks in the old-paper department, amounting to about 6.35 mgd. The various sub-drains meet at a sump in the machine shop, from which about 4.05 mgd are pumped to the steam condenser and then flow to the main ditch. The remainder discharges to the East Branch (D-5).

The drain which carries the condensate and barometric-seal water from the Swenson evaporators and also some sewage and street drainage, has a flow of about 4.32 mgd and a BOD of only 15 ppm. As might be expected, most of the solids in this effluent are dissolved. The only other significant source of discharge to the river is the effluent from Riley Run which receives the overflow from the Dill Hill lagoon. This waste will be discussed in the next section.

The Water Filtration Plant

The water filtration plant on the East Branch discharges waste wash water and sludge into the river. While the organic matter in such wastes is merely that which was originally present in the East Branch water, the treatment plant serves to concentrate the organic matter into slugs. Furthermore, the coagulating chemicals produce a voluminous floc which increases sludge banks in the river or in Piney Reservoir. On the basis of wash-water quantities of 3% to 5% of the water treated, the quantity of waste discharged from the treatment plant is estimated to be 0.6 to 1.0 mgd.

TABLE 18. NEW YORK AND PENNSYLVANIA COMPANY, JOHNSONBURG, PENNSYLVANIA, SUMMARY OF PRELIMINARY INDUSTRIAL WASTE SURVEYS SAMPLED IN OCTOBER AND NOVEMBER, 1948

Sampling Point	Date	Sample No (1)	Total Daily Discharge in mg	Temp. °C	5-Day, 20°C B.O.D.		Total Solids			Suspended Solids			Dissolved Solids			pH	Alkalinity (+) or Acidity (−) to pH 4.30 as $CaCO_3$	
					ppm	lbs/day	ppm	lbs/day	% Volatile	ppm	lbs/day	% Volatile	ppm	lbs/day	% Volatile		ppm	lbs/day
Main sulfite ditch, at weir	Oct. 22	D-1	12,300	24	402	41,200	2,872	294,300	35 8	1,252	128,300	30.9	1,620	166,000	44 0	7 03	+ 610	+62,500
Effluent from Link-Belt tank	Oct. 22	D-2	3 000	24	259	6,420	1,930	48,200	39.3	348	8,700	73.7	1,582	39,500	31.8	7 02	+ 118	+ 2,950
Blacksmith drain, at lagoon	Oct. 22	D-3	0 040	40	133	50	70,500	23,500	56.9	69,000	23,000	....	1,500	500	....	10.83	+ 1,810	+ 670
Whiting plant drain, at lagoon	Oct. 22	D-4	0 013	22	42	5	47,664	5,160	2.5	42,900	4,650	2.2	4,765	520	3.3	11.50	+63,000	+ 6,820
White-water waste channel, at weir	Oct. 22	D-5	2 510	56 to 91	66	1,270	1,846	55,500	30.0	500	9,600	36.0	1,346	25,900	27 8	7.10	+ 175	+ 3,350
Soda-mill waste channel, at weir	Nov. 2	D-6	0 650	27	351	1,900	2,130	11,500	45.0	448	2,430	100 0	1,682	9,100	39.3	10 61	+ 655	+ 3,550
Whiting-plant waste channel, at weir	Oct. 22	D-7	0 078	20	0	0	1,670	1,090	10.6	488	320	22 0	1,182	770	5 5	11.40	+ 1,055	+ 705
Sweeten evaporator drain, at mouth	Oct. 22	D-8	4 320	50	15	540	860	30,950	12 1	136	4,895	44.2	724	26,060	6.3	7.70	+ 60	+ 2,160
Dill Rill influent, at weir	Oct. 26	D-11*	0 870	15	472	3,420	7,960	57,250	48.5	6,101	44,240	52.1	1,796	13,020	36 4	10 43	+ 1,525	+11,050
Dill Rill effluent, at weir	Oct. 26	D-12**	0 750	10	203	1,270	1,922	12,010	51 2	524	3,270	48 1	1,558	8,730	24.9	8 00	+ 715	+ 4,470
Mouth of Riley Run	Oct. 26	D-13**	0 730	11	158	960	1,764	11,020	34.0	600	3,500	49.0	1,164	8,320	29.6	8 02	+ 615	+ 3,640
Bleach plant, caustic cooling water	Nov. 2	D-14	....	21	1	.	1,019	....	19 2	55	..	100 0	966	....	14 8	7 96	+ 61	+ .
Steam turbines, cooling water	Nov. 2	D-15	....	42	4	.	1,800	....	23 2	174	..	58.0	1,626	....	19.5	8 83	+ 70	+ .
Drain from bleach-house lagoon	Nov. 9	D-16	0.006				11,932	600	8.8	429	21	41.9	11,528	579	7.3	11.86	+ 5,400	+ 270
Sulfite waste liquor (to extract plant)	Nov. 16	D-17	0 145	76	24,000	28,990	103,010	124,400	74 0	0*	0*	0*	103,010*	124,400*	74.0*	2.17	− 2,700	− 3,260
Total Wastes Produced (D-1, 2, 4, 5, 6, 7, 8, 11, 16, 17)[2]			20 232		....	37,375		584,250			217,460	....		566,850	....	....		+87,290
Total Wastes Discharged to River (D-1, 5, 6, 7, 8, 13, 16)			20 414		....	45,990	....	584,960		....	118,070	....	....	236,930				+76,400
% Removal (Including Extract Plant)			0 318			31,425		397,290			99,390			129,920				+11,390
			1.5%			40.7%		31 1%			31.9%			35 4%				13.0%
Total Wastes Produced (D-1, 2, 4, 5, 6, 7, 8, 11, 16)			20 382			48,385		459,850			217,460			242,450				+91,050
			0 173			2,485		74,890			99,390			3,520				+14,640
% Removal (Excluding Extract Plant)			0.8%			5.1%		16.3%			31.9%			2.3%				16 1%
Old Paper Wastes, % Removed in Mouth of Riley Run (From D-11 to D-13)			13.8%			71.1%		80 8%			94.5%			54 6%				65.3%

(1) D-9 and D-10 were grab samples corresponding to D-4 and D-7.
(2) D-12 and D-13 were 24-hour composite samples.
(3) All tests on same flow proportion as daily rate or noted.
(4) Assuming all solids are dissolved, which is almost true.
(5) Including evaporated soda liquor but excluding evaporated sulfite liquor

TABLE 19. SUMMARY OF BOD RESULTS FROM SURVEY OF MAIN-DITCH COMPONENT WASTES

Period	Jensen Tower Waste lbs/day (a)	Extract Plant Condensate, lbs/day (b)	Extract Plant Floor Drain, lbs/day (c)	Oliver Washer Effluent, lbs/day (d)	Oliver Thickener Effluent, lbs/day (e)	Rogers Machine Save-all, lbs/day (f)	Rogers Machine Spray Water, lbs/day (g)	Steam Condenser Effluent, lbs/day (h)	Weak Sulfite Waste Liquor mgd (i)	Weak Sulfite Waste Liquor lbs/day (j)	Total of Gaged Wastes mgd (k)	Total of Gaged Wastes lbs/day (l)	Main Ditch mgd (m)	Main Ditch lbs/day (n)
First 24-hr Period	.109	895	—*	2005	1113	935	....	2220	0.415	10,480	11.47	17,760	12.86	14,560
									0.535	6,830	11.36	13,670	12.69	24,690
									0.310	12,750	11.34	20,010	12.87	*34,400
Second 24-hr Period	.135	727	190	2760	1260	597	....	2220	0.315	13,200	11.34	21,120	13.05	*31,300
									0.289	10,910	11.32	18,860	12.97	26,000
									0.399	6,780	11.43	14,700	11.87	21,600
Third 24-hr Period	.122	30	65	1735	1085	660	12	2220	0.445	6,320	11.47	12,830	12.91	12,400
									0.409	9,800	11.44	14,351	12.64	19,550
									0.321	4,800	11.35	9,331	..	
Average	123	751	128	2173	1155	731	12	2220	....	9,050		16,341	.	19,760
% of Main Ditch	0.62	3.80	0.61	11.0	5.83	3.69	0.06	11.2	....	45.7	. .	82.7	.	100%
% of Gaged Wastes	0.75	4.60	0.77	13.3	7.05	4.46	0.07	15.5	....	55.3	...	100 0		

*Abnormal high values caused by leaking pans in extract plant, not included in averages.

Note. Flows for columns (a) through (h) as follows:

(a) — 0.200 mgd
(b) — 0.133 mgd
(c) — 0.010 mgd
(d) — 1.055 mgd
(e) — 1.450 mgd
(f) — 1.300 mgd
(g) — 0.172 mgd
(h) — 4.015 mgd

The totals of all of the wastes produced at the mill and discharged to the stream are presented in Table 18. The significance of these totals and their comparison with observed loadings in the river are discussed at the end of the following section.

Existing Treatment Works and Their Efficiency

The facilities which have been (or are being) constructed by the New York and Pennsylvania Company expressly for the purpose of pollution abatement comprise:

A. An extract plant for the disposal of strong SWL.

B. The displacement washing system in the sulfite blow pits to reduce the quantity and strength of weak SWL.

C. A lagoon to take the strong SWL when the extract plant is out of operation.

D. Primary settling tanks for the wastes from the main drain.

E. The Dill Hill lagoon, including pump and pipelines, for the treatment of most of the old-paper waste.

F. The black-ash basin for the retention and de-watering of carbon granules from the rotary furnaces.

G. The bleach-plant basin for the removal of chlorinated lime sludge.

In addition the Company has installed, is installing, or is planning to install several facilities which serve to reduce stream pollution, although their primary justifications are for other purposes, as follows:

H. The Infilco Clarator (or Cyclator) which will remove fiber and other suspended solids from white water so that such water may be reused in the various mills. In effect it is a huge save-all and should materially improve the quality of recirculated water. It cannot be charged to pollution abatement alone unless the clarified effluent is discharged to the stream, in which case it would have been cheaper to have treated these wastes in conjunction with the main-drain wastes.

I. The Impco counter-current washer, which minimizes the loss of black liquor from the brown-stock pans and overflows from old storage tanks. Its installation increases the efficiency of soda recovery, which is an integral part of any soda mill. Furthermore it can be operated with about one-third of the labor force required for the facilities which it replaced. It appears to be economically justified without relation to pollution abatement.

J. The Swenson evaporators and the Greenewalt furnace in the soda mill. These units are an essential part of the soda process and are only incidental to stream improvement in that without them the use of rotary furnaces exclusively would cause greater pollution.

K. The Laughlin filter for the effluent from the #5 and #6 paper machines. Reputedly installed as a stream-improvement measure, this unit provides no pollution abatement whatsoever inasmuch as the backwash water is discharged to the main ditch. It serves only to improve the quality of water used on the #1 machine showers.

A brief description of the principal features of each of the important pollution-abatement works and an evaluation of their pollution-abatement efficiencies are presented below. The displacement washing system will be considered in conjunction with the extract plant since their efficiencies are inter-related.

Displacement Washing System and Extract Plant

The extract plant takes strong SWL and converts it into a product called Clarion Extract which is sold for road stabilization or for use as an organic binder. The Company was reticent to release many of the details of the process and the data discussed herein are those which are related to the effectiveness of this plant in removing BOD, solids and other pollutants.

The displacement washing system is a quasi counter-current wash for the sulfite pulp in the blow pits. Essentially it consists of several washings of the pulp with successively cleaner waters, with reclamation of the cleaner used wash waters for re-use on dirtier pulp. A diagrammatic sketch of the method is presented in Fig. 15. The waste waters are turned to the river whenever the specific gravity drops below 1.5° Baume (corresponding roughly to a temperature of 110°F). Stronger waste waters are recovered and pumped to the weak-liquor storage tank.

The complete first-stage BOD curve for strong SWL was determined for a grab sample taken at the control desk on November 16, 1948, and also for a sealed ampoule of strong SWL used as a standard in the Company's laboratory. The results of these two determinations, generalized in terms of 1,000 ppm of total volatile solids (TVS), are shown in Fig. 16 and display remarkable agreement. The average of the 5-day BOD values for these two curves is 302 ppm per 1,000 ppm of TVS. A similar generalization of four tests of the weak SWL gave values of 240, 335, 337 and 302 ppm with an average of 304 ppm of 5-day BOD per 1,000 ppm of TVS. It follows, therefore, that the BOD of strong or weak SWL at this plant is about 300 ppm per 1,000 ppm of TVS. Furthermore, the TVS of strong SWL is about 77.5% of the total solids and the average total solids before evaporation is about 12.5% (125,000 ppm). Hence, strong SWL of 12.5% total solids would have a computed 5-day BOD of about 29,000 ppm. Parenthetically it might be noted here that data submitted by the New York & Pennsylvania Company to the Department of Health on April 5, 1949, for the purpose of determining normals in respect to pollution equivalents for sulfite liquor, showed the 5-day BOD of combined strong and weak SWL to be only 198 ppm per 1,000 ppm of TVS.

With the displacement washing system in operation, we found the total 5-day BOD produced by the sulfite mill to be 54,710 lbs per day, divided as follows:

Source	*Flow, gpd*	*BOD, lbs per day*
Strong SWL, to extract plant	172,300	41,600
Weak SWL, to river	363,000	9,050
Oliver washer effluent	1,685,000	2,170
Oliver thickener effluent	3,450,000	1,150
Rogers machine spray	198,700	10
Rogers machine save-all	1,350,000	730
		54,710

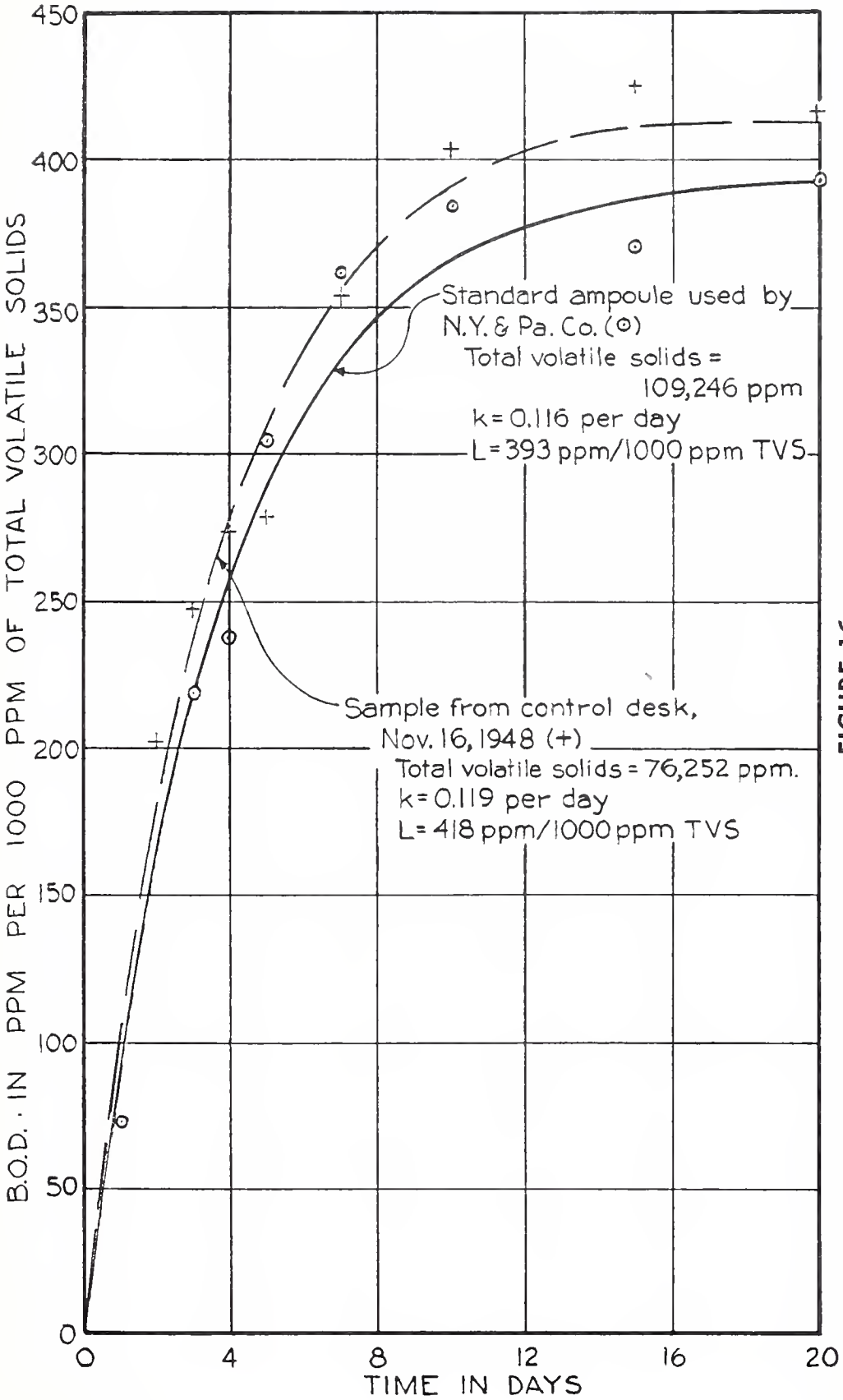

FIGURE 16.
COMPLETE BOD CURVES FOR STRONG SULFITE WASTE LIQUOR
(At N. Y. & Pa. Co. Johnsonburg Mill)

On the basis of an estimated 100 tons of pulp being produced each day, the BOD was 547 lbs per ton of pulp. Of this amount, the BOD actually removed was that of the strong SWL, 41,600 lbs per day less 880 lbs per day of BOD from the condensate and extract-plant floor drains or 40,720 lbs per day, making the over-all efficiency of BOD removal in the sulfite mill 74.5%. Based on the total of strong and weak SWL alone, the BOD removal was 80.5%.

Prior to the use of the displacement washing method, approximately 145,000 gpd of SWL were evaporated and the over-all efficiency of BOD removal in the sulfite mill was about 62.5%, or for the SWL alone about 67.4%. With a highly efficient counter-current washer, such as the new Impco washer in the soda mill, we estimate that about 95% of the BOD attributable to SWL could be removed (see later discussion of possible alternate treatment methods).

Sulfite Waste Liquor Lagoon

The evaporators and filters in the extract plant require considerable maintenance and attention, owing primarily to the precipitation of calcium sulfate. Whenever the plant must be shut down for cleaning, the surplus strong SWL is supposedly diverted to a large lagoon which is situated on the west bank of the Clarion River about two miles below the mill. Constructed in the summer of 1941, this lagoon has an area of about 15.5 acres and a usable capacity of about 50 mg. At the downstream end of the lagoon there is an effluent gate house, but it is understood that no discharge from the lagoon to the river can be made without specific permission of, and supervision by, the Sanitary Water Board or its engineers. Strong SWL diverted from the extract plant flows through an 8-in. lead pipe to a point beyond the Pennsylvania Railroad tracks, then through an 8-in. wood stave pipe to a point near the lagoon, from which it is pumped through a 4-in. force main to an open ditch leading to the lagoon.

Considerable difficulty has been experienced from the use of this alternate disposal method with the result that it has not operated much of the time and the surplus SWL has been discharged to the river. Leaks have developed in the pipeline and sump, and the booster pumps have been inadequate. The lagoon showed very little evidence of extensive use up to September, 1948, when we commenced our river surveys, but from October to December, 1948, we observed that surplus SWL was frequently discharged to the lagoon.

Primary Settling Tanks

The main drainage ditch, carrying the wastes as described hereinbefore, passes through a culvert under the railroad tracks and skirts the black-ash lagoon as shown in Fig. 13, before discharging into the Clarion River. A 12-ft weir has been constructed near the end of this ditch for accurate measurements of flow. Just upstream from the weir there is located a diversion intake, shielded by a coarse rack, from which a 24-in. pipe leads to the pump sump for the existing primary settling tank. A portion of the wastes are then pumped to the settling basin at rates varying between 3.0 and 6.5 mgd. The settling tank has an effective length of 140 ft and a width of 33 ft with an average water depth of 12 ft. It was originally built as a "trial" sedimentation basin with the understanding that similar basins would be

built later if the present design proved that effective removal of settleable solids could be obtained. It is now proposed to construct two similar settling tanks east of, and parallel to, the present basin. It is also proposed to construct a new screening and pumping station adjacent to the northwest side of the Infilco Cyclator and a new channel to divert all of the main-drain wastes to this station (see Fig. 13). The new pumping station will be equipped with a trash rack and also a mechanical traveling screen for the removal of coarse solids which might clog the pumps. It is proposed to install three vertical submerged pumps of 7.2 mgd capacity each, two of which will be operated steadily under normal conditions. The pumps will discharge to a header leading to the three sedimentation basins and will replace the pumping system for the existing tank. Sludge from the three tanks will be drawn to a sump from which it will be discharged to the wet well of the nearby Dill Hill pumping station.

When completed, the three settling basins will have a total area of 13,850 sq ft and a total volume of 1,247,000 gallons. For an average flow of 12 mgd, the surface area overflow rate will be 866 gpd per sq ft, the detention period will be 2.5 hours and the longitudinal velocity will be 0.934 ft per minute. These design factors are consistent with accepted practice for municipal treatment works.

The Company has spent considerable time and money in a series of tests on the first settling tank to determine the efficiency of removal of settleable and suspended solids at varying depths. Moreover, the National Council for Stream Improvement (NCSI) conducted a series of tests with a small pilot plant, the results of which are published in the NCSI Technical Bulletin No. 17. The results of settling tests conducted by the New York and Pennsylvania Company, by the Pennsylvania Department of Health and by the NCSI are presented in Fig. 17. Approximately 70% of the suspended solids in the main-drain wastes were removed at the anticipated overflow rates and at flow depths of 10 ft or 12 ft. At the 8-ft depth or at higher overflow rates, the efficiency of suspended solids removal was decreased. On the basis of these tests (and because it was desirable to have the flow line of all sedimentation units at the same level) it was decided to construct the two additional basins with a 12-ft water depth.

While the data presented in Fig. 17 indicate that approximately 70% removal of suspended solids may be anticipated in the primary settling tanks, the effectiveness of these tanks in removing BOD is subject to speculation. The results of the tests by the Department of Health on the first settling tank, conducted in the fall of 1948, showed a maximum BOD removal of 37.1% (at an 8-ft depth with an overflow rate of 936 gpd per sq ft), a minimum BOD removal of —37.8% (at a 12-ft depth with an overflow of 1,040 gpd per sq ft), and an average BOD removal of 5.6% for all tests. The results obtained by the Company showed a maximum BOD removal of 23.2% (at an 8-ft depth with an overflow rate of 765 gpd per sq ft), a minimum BOD removal of —10.5% (at an 8-ft depth with an overflow rate of 1,140 gpd per sq ft), and an average BOD removal of 10.6% for all tests. The extreme variations in these results are probably attributable to the fact that samples collected simultaneously at inlet and outlet do not reflect changes in strength because of the detention time of about 2.5 hours. We feel however that the average of all the tests is reasonably representa-

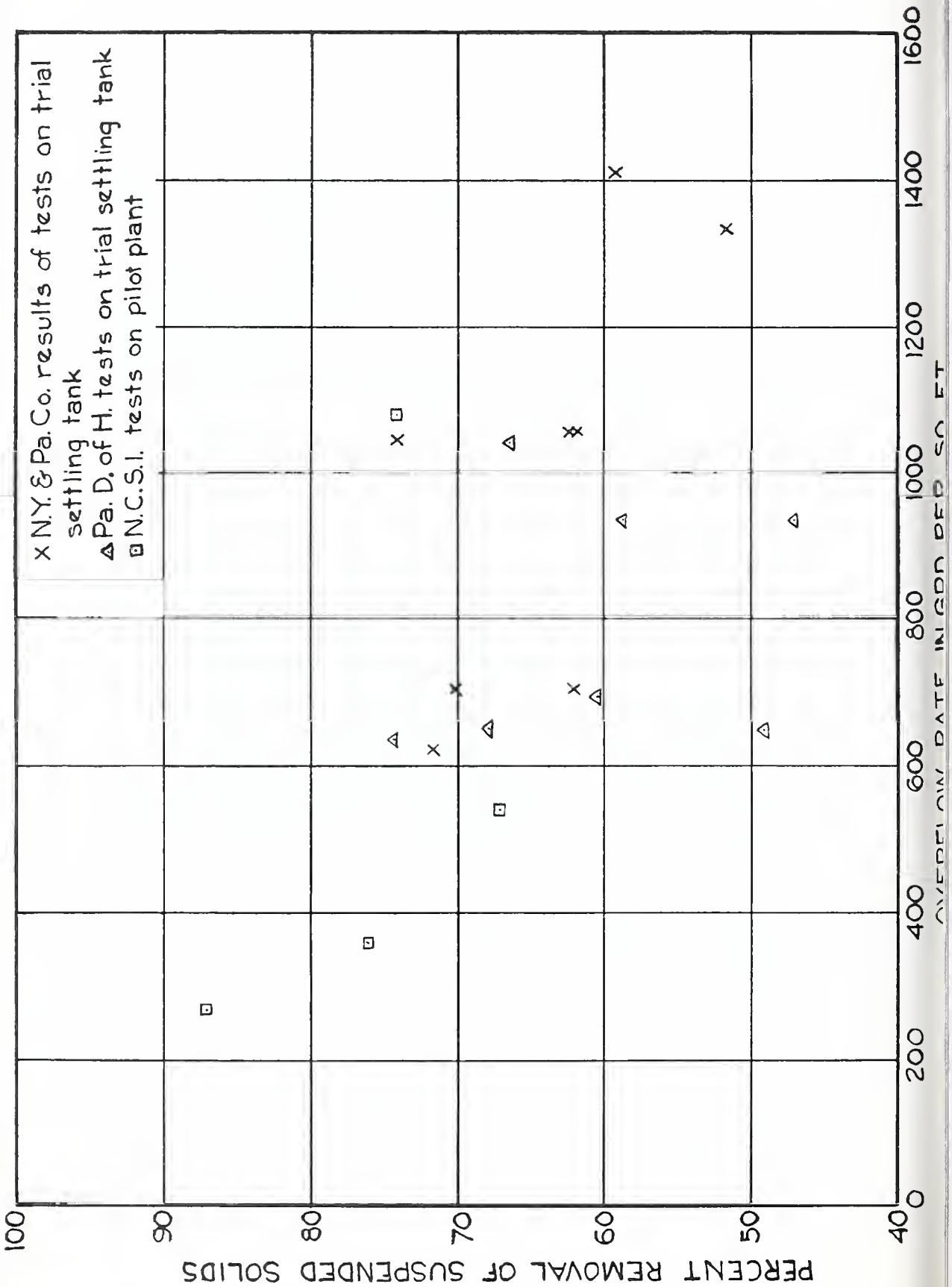

FIGURE 17. SETTLING CHARACTERISTICS OF MAIN-DRAIN WASTES

tive of the BOD removal to be anticipated. For the pilot plant tests conducted by the NCSI on the main drain wastes, an average BOD removal of 12% was reported.

Rather than duplicate the work of the Department of Health, the NCSI and the Company, we approached the problem of BOD removal in another way. Composited samples of the main-drain wastes were passed through filter paper and the complete first-stage BOD curve was obtained for the filtered and unfiltered samples. The results of these tests, presented in Fig. 18, show the BOD of the unfiltered samples to be 432 ppm for five days and 468 ppm for the ultimate first-stage value. For the filtered sample, the 5-day BOD was 385 ppm and the ultimate first-stage BOD was 435 ppm. Thus it is seen that filtration effected a 10.9% removal of the 5-day BOD and a 7.05% removal of the ultimate first-stage BOD. These differences represent the BOD which was caused by the suspended solids removed on the filter paper. If we assume 70% removal of suspended solids in the settling tank, then the removal of 5-day BOD would be 7.6%. On the basis of this analysis and the average results of the aforementioned tests by the Pennsylvania Department of Health and the Company, we conclude that the BOD removal by primary sedimentation of main drain wastes will be no greater than 12%.

The various tests that have been run by our engineers and others indicate that the primary settling basins will remove approximately 26% of the methyl-orange alkalinity, 50% of the turbidity, practically none of the sulfites, and none of the color.

We have estimated the volume of sludge to be expected from the three primary settling tanks on the basis of data obtained by our engineers and others. For an average suspended-solids content of 400 ppm in the main-ditch wastes, 70% removal by settling, and a moisture content of 97.5% in the sludge, we estimate the sludge production to be 133,000 gpd, or 1.11% of the flow in the main ditch. The sludge solids are expected to be approximately 30% volatile, the high ash content being caused by filler in the waste waters and the precipitation of $CaCO_3$ and $CaSO_4$. The problem of disposal of this sludge is discussed in conjunction with the Dill Hill system.

The Dill Hill Lagoon

Old-paper wastes from the first group of Lancaster washers and calcium monosulfite filter cake from the SWL extract plant flow through an 18-in. asbestos-cement pipe to an 8 ft x 16 ft x 3 ft sump in the Dill Hill pump station (see Fig. 13). Wastes from the whiting plant (D-4) formerly were also discharged to this sump but their mixture with the other wastes caused excessive $CaCO_3$ deposition in the pipeline and necessitated too-frequent cleaning. At the pumping station there are three high-lift pumps arranged so that any two may be operated in series, with the third as a stand-by. Although the rated capacity of these pumps was reported to be 1,000 gpm (1.44 mgd), the maximum flow as gaged at the inlet to the Dill Hill lagoon was only 1,015 mgd. The pumps are driven by 100 HP electric motors and operate normally against a dynamic head of about 170 psi (392 ft). Pumping costs in 1947 averaged $626 per month and in the first ten months of 1948, $563 per month. Considering the cost of electricity at 1¢ per KWH and an estimated 60% efficiency (electricity to water) we have computed the average 1947 pumpage to be 1.01 mgd and that of 1948 to be 0.91 mgd.

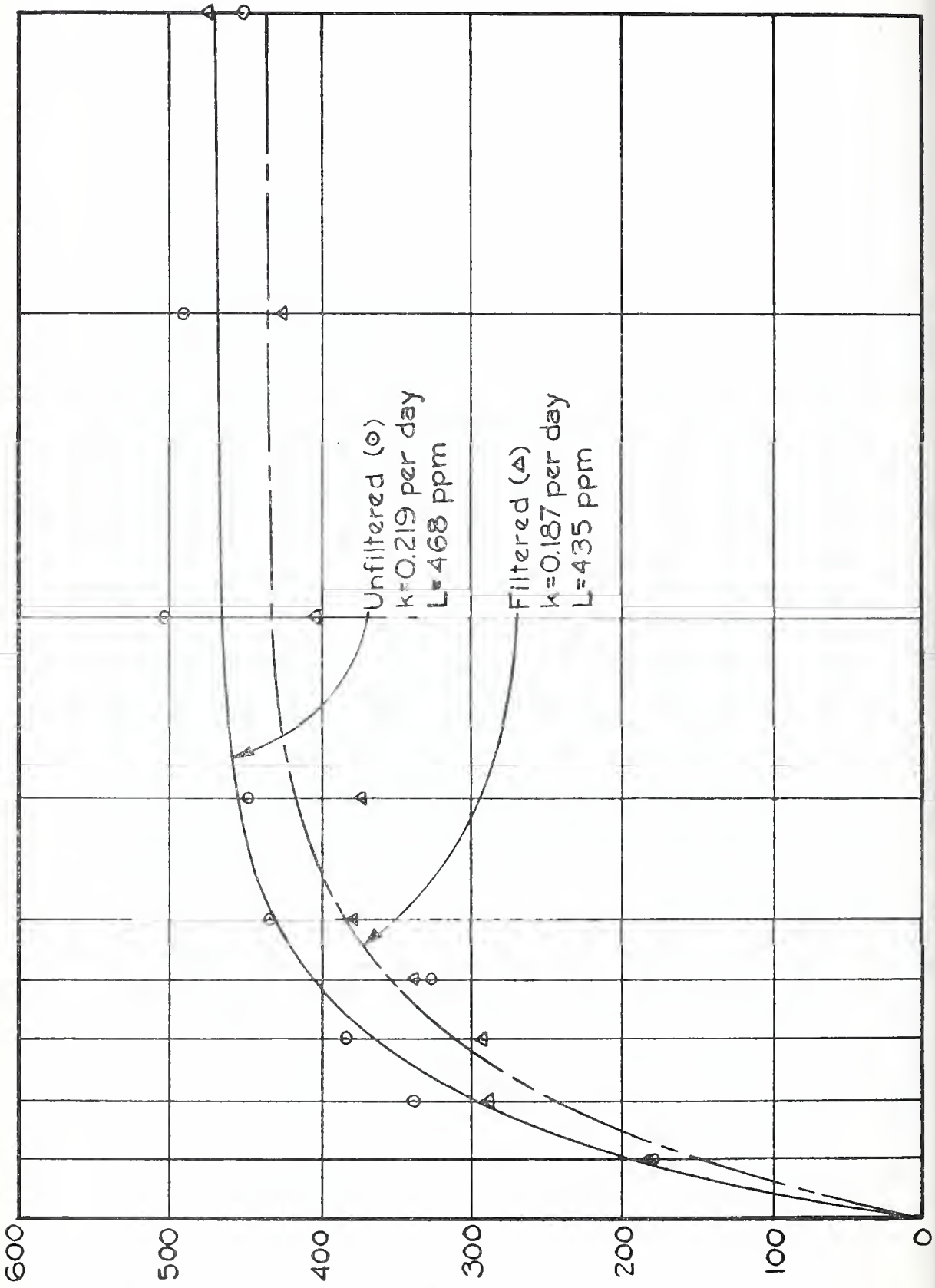

FIGURE 18. EFFECT OF REMOVAL OF SUSPENDED SOLIDS ON THE BOD OF MAIN-DRAWN WASTES

On the day of our 8-hour gaging of the influent to Dill Hill lagoon, the average flow was 0.87 mgd.

From the pumping station a 12-in. asbestos-cement pipeline about 6,500 ft long carries the wastes to the Dill Hill lagoon, located on a high plateau southwest of Johnsonburg (see Fig. 1). The elevation of the outlet of the pipeline is 338.50 ft higher than the center line of the pumps and the highest point on the pipeline (about 500 ft short of its point of discharge) is 355.07 ft higher than the pumps. The dynamic head on the pumps averages about 170 psi (392 ft) and hence the friction head is about 37 ft, and the slope of the hydraulic grade line is 0.0061. For a flow of 1.0 mgd, the corresponding friction coefficient in the Hazen-Williams formula is computed to be 56 and for a flow of 0.87 mgd it is 50, in contrast to normal values of 120 to 140 for clean asbestos-cement pipe. These low coefficients certify the presence of excessive incrustation which the Company's engineers have found in the pipeline. It is understood that the pipeline has had to be cleaned one or more times each year and during such clean-outs the old-paper and filter-cake wastes are diverted to the main ditch. The Company has recently inserted a special clean-out connection to facilitate this operation and reduce the time when the pipeline is out of service, but nevertheless the cleaning operation represents a breakdown in the treatment routine.

A second difficulty with the pumping and piping arrangement is the fact that whenever the flow of wastes at the mill becomes too great the excess spills over into the main ditch through the overflow conduit mentioned hereinfore. Such a condition occurs when recirculation from the first Lancaster wash-water cylinders to the flat screens is temporarily stopped. Overflows also occur when the pumps are out of operation.

The Dill Hill lagoon, constructed in 1938, has an area of 55 acres and impounds about 145 mg. For an average flow of 0.87 mgd, it provides a detention period of over five months. The effluent is discharged over a broad-crested weir and cascades down Riley Run about 1.7 miles to the Clarion River (see Fig. 1). To measure the flow into and out of the lagoon we used the weir boxes which the Company had installed at the end of the 12-in. force main and at the head of Riley Run. Our gagings showed the effluent discharge rate to be 0.75 mgd, or 0.12 mgd less than the corresponding influent rate of flow. Inasmuch as the weather was extremely dry and the lagoon is on a hilltop, this difference can be accounted for by evaporation alone, corresponding to an average annual rate of evaporation of 27.7 inches per year. Seepage may also serve to reduce the overflow. On the other hand during wet weather the effluent will exceed the influent.

Our tests on the effectiveness of Dill Hill lagoon in removing pollution showed a 63% reduction of BOD, a 79% reduction of total solids, a 92.6% reduction in suspended solids, a 59.5% reduction in methyl-orange alkalinity and a reduction in pH from 10.45 to 8.00. The wastes entering the lagoon are dirty grey and turbid in appearance, and heavily laden with filler. The effluent is black and semi-turbid, with a strong putrescent odor. Our analysis showed the sulfide content of the effluent to be 11.4 ppm. Other analyses are presented in Table 18.

Riley Run provides a further reduction in polluting substances and serves to add oxygen to the wastes which are anaerobic as they leave the lagoon. Our analyses (see Table 18) show that Riley Run itself effects a

22% reduction of BOD, 8.2% of total solids, 23.5% of suspended solids, 14.0% of methyl-orange alkalinity and practically no change in pH. Aeration in Riley Run lowered the sulfides from 11.4 ppm to 1.4 ppm, a reduction of 87.7%, and added 3.39 ppm of dissolved oxygen to the wastes. For Dill Hill lagoon and Riley Run combined, the over-all reductions were found to be 71.1% for BOD, 80.8% for total solids, 94.3% for suspended solids and 65.3% for methyl-orange alkalinity. The Riley Run effluent was still black and turbid in appearance but had no preceptible odor. Foam which was first observed at the head of Riley Run was still being formed by cascades near the foot of the run and the foam so formed persisted in the river for many miles, re-occurring at each point of turbulence.

It is understood that the Company plans to drain sludge from the primary settling tanks to the sump of the Dill Hill pump station and thence to pump it to the Dill Hill lagoon. It is further understood that the existing pumps have been found to be unsuitable for this purpose, because of the high-solids content of the sludge, and that new pumps are being purchased.

There is considerable speculation as to how long Dill Hill lagoon can be used, that is, the time required for it to be filled with sludge. The Company attempted unsuccessfully to determine sludge depth by soundings throughout the reservoir last year, and also had aerial photographs taken to show the extent of the delta formed by deposited sludge. These photographs reveal that during the first ten years of operation the old-paper wastes have formed a delta over the upper 10 to 20% of the area.

From the average suspended-solids content of the old-paper wastes, as determined by several investigators, and a flow of 0.87 mgd, with assumption of 92.5% removal of suspended solids, 75% reduction of volatile solids by benthal decomposition, and 75% moisture in the consolidated sludge deposits, we have estimated the rate of accumulation of permanent sludge in the lagoon to be 8,500 gpd, or 3.1 mg per year. For the first ten years of its operation, this rate of accumulation would produce 31 mg or 21.4% of the reservoir capacity. If that rate of accumulation were to continue, we could expect the present Dill Hill lagoon to be used for about 40 more years. A complicating factor, however, is the primary-settling-tank sludge which will be pumped into the lagoon as soon as pumps are available. With assumptions somewhat similar to those described above, and the previously described figure for the volume of primary-settling-tank sludge, we have calculated the ultimate consolidated volume of primary-settling-tank sludge in Dill Hill lagoon to be 8,100 gpd, or about equal of that of the old-paper sludge. Hence, when the main-ditch sludge is pumped to Dill Hill lagoon, we may expect the lagoon to accumulate sludge twice as fast as it is now doing, thereby reducing its useful life to about 20 more years. In the event that secondary biological treatment of main-drain wastes is undertaken and the secondary sludge pumped to Dill Hill lagoon, we estimate that the useful life of the present lagoon will be reduced to about 13 years. It is understood that, if need be, the dike which forms Dill Hill lagoon can be raised considerably so as to extend the useful life of that phase of the treatment works.

In view of the high cost of pumping old-paper wastes to the Dill Hill lagoon, we have considered the possibility of mixing the old-paper wastes with the main-drain wastes and treating them jointly in the primary settling

tanks and in possible secondary works. We find, however, that such mixing is not desirable for the following reasons: (a) the pH of the mixture has been found to be about 9.5 which is too high for subsequent biological treatment and too high for direct discharge into the river at drought flow, (b) the BOD and suspended solids in the old-paper wastes will not be reduced as effectively by primary settling as in the lagoon, and (c) the BOD load of the old-paper wastes would be added to the river at Johnsonburg where the assimilative capacity of the stream is less than at the mouth of Riley Run. We recommend, therefore, that the present method of disposal of old-paper wastes be continued.

The Black-Ash Basin

The black-ash basin was originally constructed in May, 1948, with an area of 2.72 acres. Since that time the level of the dike forming the basin has been raised twice for a total of about 7 ft, and it is understood that the gas house shown on Fig. 13 has since been removed and the basin extended to have a total area of 2.99 acres. The purpose of the black-ash basin is to prevent carbon granules produced in the rotary furnaces of the soda mill from entering the river. The basin serves this purpose well and, as shown below, keeps a tremendous accumulation of solids from the river.

The analyses in Table 18 show the suspended-solids content of drains D-3 and D-4 to be 27,650 lbs per day, with a total BOD of only 55 lbs per day. The dikes of the basin are porous and let the liquid (and most of the BOD) drain to the river or into the main ditch. The black ash and calcium carbonate which remain in the basin form a compact mass having a moisture content, according to our tests, of 71.1%, and a weight of about 15 lbs per cubic foot. On the basis of these data we have computed the daily accumulation to be 6,380 cu ft, or for an area of 2.72 acres, at the rate of about 1.65 ft per month. This computed accumulation was verified by actual observation between October 22 and November 20, 1948 when the level of solid ash in the basin rose about 2 ft. At this rate of rise, the black-ash basin even with its additional 7 ft of embankment and added area cannot continue to be used for more than a few months.

We analyzed the black ash and found it to have 12.15% ash, 83.14% fixed carbon and 4.71% volatile matter. Sulfur, on a dry basis, was 0.26%. The heat value was 12,155 btu per lb of dry matter, which compares roughly with that of bituminous coal. This heat content is more than enough for the black ash to support its own combustion, and were it not for the smoke nuisance which would occur, black ash might well be hauled away to a dumping area and burned.

The Company recognizes that the present black-ash basin can be no more than a temporary expedient and that a more permanent method of black-ash disposal must soon be developed or else the production of black ash eliminated by abandonment of the old rotary furnaces. It is understood that consideration is being given to the installation of a complete Combustion Engineering system to take the place of both the rotary furnaces and the Greenewalt furnace, but that no definite decision has been made in this matter.

Bleach-Plant Basins

The two bleach-plant basins, described hereinbefore, are decanted to the East Branch for four to eight hours each day and discharge approximately

6,300 gallons of bleach liquor with a high content of dissolved mineral solids (mostly calcium), a high pH (11.9) and about 5,500 ppm (288 lbs) of total chlorine. The basins serve effectively to remove the heavy chlorinated lime sludge from the bleach-plant wastes but they do not take out the soluble substances such as chlorine. If we assume that the 288 lbs of chlorine is discharged during a 6-hour period into the drought flow of the combined East and West Branches (20.5 cfs), the chlorine dosage of the river water will be 10.45 ppm. This dosage is considerably in excess of the chlorine demand of normal river water and, were it not for the present organic wastes discharged into the East Branch from the soda mill, the bleach-plant wastes would in themselves contribute pollution in the form of toxic chlorine.

When the soda-mill wastes and other organic pollutants are removed from the East Branch, it is conceivable that the chlorine content in the bleach-plant wastes will actually cause pollution during drought flows in the short reach downstream to the point of discharge of the main-drain wastes. If such a condition is found to obtain we recommend that the bleach-plant supernatant be piped into the main drain, the wastes of which have a chlorine demand far in excess of the available chlorine in the bleach-plant supernatant.

Efficiency of Existing Treatment Works

By way of recapitulation of the foregoing information relative to the efficiency of existing treatment works (as of November, 1948), we have summarized the data presented in Table 18 and find that the total wastes discharged to the river from the New York and Pennsylvania Company had approximately the following loadings: 45,900 lbs per day of 5-day BOD, 384,960 lbs per day of total solids, 148,070 lbs per day of suspended solids, 236,930 lbs per day of dissolved solids, and 76,400 lbs per day of methyl-orange alkalinity. Attention is called to the fact that the 45,900 lbs of 5-day BOD per day so tabulated is only about half of the BOD observed in river traverses conducted by our engineers and others (see Table 9). This fact points to a cardinal point of our entire survey, namely, that pollution as measured in the river at random times without knowledge of the Company far exceeds that being discharged by the mill during announced surveys. The U.S.P.H.S. noted the same fact, as shown by the underlined passages in Chapter I. We believe that the difference between the data is due to overflows, especially of black liquor in the soda mill, and to general poor housekeeping and carelessness on the part of mill employees.

We consider that the recovery of strong black liquors is an integral part of a soda mill and since such liquor is not normally a soda-mill waste the Company should not be credited with its recovery as a pollution-abatement measure. We also consider that since sulfite liquor is not conventionally recovered the Company should be given credit for such recovery. On that basis, the total wastes produced at the mill were approximately as summarized in Table 18. These figures indicate that the Company was removing 40.7% of the BOD, about 34% of the total solids, 32% of the suspended solids, 35% of the dissolved solids and 13% of the alkalinity (the figures for solids should be modified slightly to allow for the removal of bleach-plant lime sludge). If credit is not allowed for the sulfite extract plant, the removals are shown in Table 18 to be only 5.1% for BOD, 16% for total

solids, 32% for suspended solids, 2.3% for dissolved solids and 16% for methyl-orange alkalinity.

When all of the presently contemplated improvements are completed, when the numerous breakdowns and overflows are eliminated, and when cognizance is taken of the displacement washing system in the sulfite mill (not in operation at the time of the surveys presented in Table 18), we estimate that the total BOD load of the effluents at the main mill will be about 17,000 lbs per day. This BOD load is to be compared with an allowable loading (see Table 13) of 13,200 lbs per day after the East Branch dam is in operation and only 3,150 lbs per day if no credit is allowed for the dam. This BOD load, with about 1,000 lbs per day from Riley Run, corresponds to an overall BOD removal of about 77%. The corresponding overall removal of suspended solids will be about 79%. It is evident therefore that a further degree of treatment will be required even after the complete elimination of overflows and clean-out wastes. We have investigated various methods by which further treatment may be achieved and the results of our studies are described in the next section.

Investigations of Further Treatment Methods

In order to determine the effectiveness of alternate methods of further treatment, we conducted several experiments, described below, in addition to those already referred to in this report. Tests were made of settled main-drain wastes to determine the feasibility and effectiveness of plain aeration, chlorination, biological treatment by the activated-sludge process and biological treatment by trickling filters.

The experiments with plain aeration were conducted to determine the extent to which dissolved oxygen could be added to the wastes, the rate at which equivalent sulfites would be dissipated, the reduction in ultimate BOD and the rate of BOD (k_1), and to study the characteristics of foam formation. It was thought that direct aeration might remove the sulfites and other readily oxidizable substances, including volatile acids, and might provide a residual dissolved-oxygen content in the wastes before they are discharged to the river. Samples of settled main-drain wastes were subjected to diffused-air aeration in an inverted Erlenmeyer flask for periods of 2, 4½ and 6 hours. The raw wastes and aerated samples were analyzed for dissolved oxygen, equivalent sulfites, odor, appearance and BOD (see Fig. 19). It was found that plain aeration had no significant effect upon the appearance and odor of the wastes. The results of other determinations are summarized as follows:

Aeration Period in Hours	*Equivalent Sulfites in ppm as SO_3*	*Dissolved Oxygen in ppm, one hour after aeration*	*Ultimate First-Stage BOD, L_1, in ppm*	*Rate of BOD (k_1) per day*
0	22.1	0	281	0.155
2	7.0	0	273	0.138
4½	8.4	0	272	0.114
6	7.2	0	268	0.174

From these experiments we conclude: (a) that plain aeration dissipates about two-thirds of the equivalent sulfites in less than two hours but the residual sulfites are persistent, (b) that plain aeration of settled main-drain wastes is not effective in providing a residual dissolved-oxygen content, and

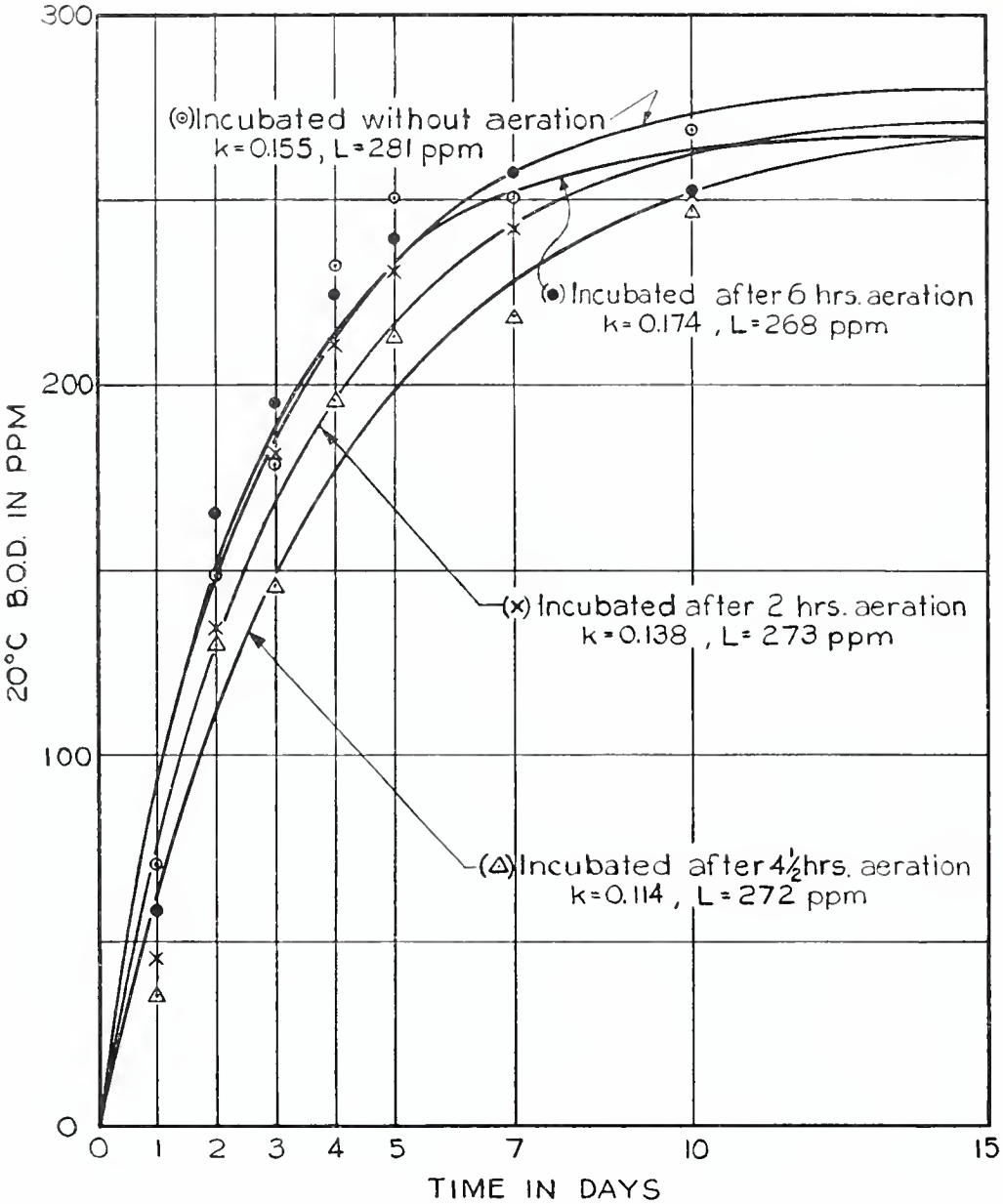

FIGURE 19.

EFFECT OF AERATION ON THE BOD OF MAIN-DRAIN WASTES

that such aeration will be effective only after secondary biological treatment, and (c) that plain aeration has little, if any, effect upon reduction of the magnitude or rate of first-stage BOD.

From our test of foaming of main-drain wastes subjected to diffused-air aeration, we observed: (a) that foam built up to a constant depth of one-half inch to one inch after which the rate of dissipation balanced the rate of formation, (b) that the depth of foam varied directly with the amount

of air supplied, with additional air causing excess foaming, (c) that finer bubbles caused deeper foam, (d) that the depth and persistence of foam increased with the content of SWL in the main-drain wastes, the SWL appearing to form a tougher film around the air bubbles in the foam, and (e) that the depth of foam was just as great after six hours of aeration as it was at the beginning of the experiment. It is probable that foaming is caused by long-chain resinous compounds in the SWL and other waste products and that, until such complex resins are broken down by biological action, foam will continue to form each time that the wastes are subjected to aeration. From these experiments we believe that the main-drain wastes could be subjected to plain aeration without excessive foaming, provided that the concentration of weak SWL is kept to a minimum by proper counter-current washing and provided also that no strong overflow or clean-out wastes are discharged to the ditch. We do not recommend, however, that plain aeration alone be practiced in view of its ineffectiveness in reducing BOD, odor and sulfites.

Effect of Chlorine on Main-Drain Wastes

Experiments were also conducted to determine the effect of chlorine upon the equivalent sulfites, the first-stage BOD curve, the odor and the appearance of the wastes. It was expected that the chlorine would completely oxidize the equivalent sulfites and in so doing possibly reduce BOD. There was also the possibility that complex chloro-organic compounds would be formed which were less readily susceptible to bacterial action, thereby reducing the rate of BOD (k_1) and extending the oxygen demand over a longer period of time. A sample of settled main-drain wastes was treated with sodium-hypochlorite solution and the chlorine demand for a 10-minute contact period was found to be 136 ppm. Four samples of the wastes were then treated with 0, 42, 94 and 136 ppm of chlorine, corresponding approximately to 0, 31, 69 and 100% of the chlorine demand. After a 10-minute contact period each sample was analyzed for pH, alkalinity, equivalent sulfites, and complete first-stage BOD (see Fig. 20). Observations were also made of appearance and odor.

Chlorination changed the color of the main-drain wastes from grey to a pinkish grey, and the pungent sulfite odor to a sweet odor which was not unpleasant and not unlike that of the river water below Piney Dam. The results of other determinations are as follows:

Chlorine Dosage, % of demand	*Equivalent Sulfites in ppm as SO_3*	*pH*	*Ultimate First-Stage BOD, L, in ppm*	*Rate of BOD (k_1) per day*
0%	24.5	7.43	274	0.194
31%	1.6	7.24	284	0.137
69%	0	7.20	286	0.139
100%	0	7.16	286	0.127

These results show that chlorination is very effective in oxidizing equivalent sulfites, even in dosages less than one-third of the chlorine demand They also show that chlorine does not lower the ultimate first-stage BOD, but it does slow down to a slight extent the rate at which such BOD is

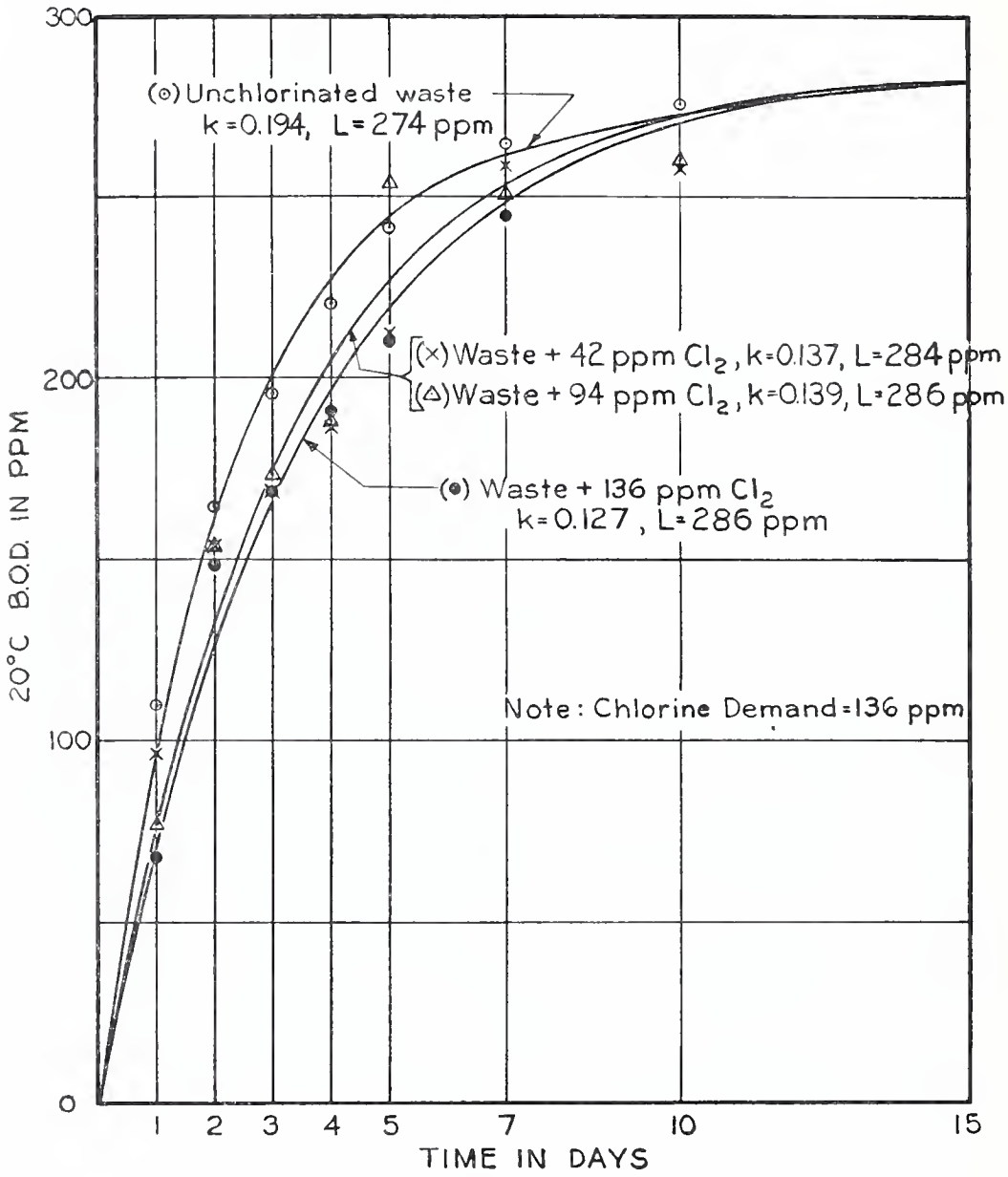

FIGURE 20.

EFFECT OF CHLORINATION ON THE BOD OF MAIN-DRAIN WASTES

exercised. The principal attribute of chlorination of these wastes is the effective reduction of sulfites and the improvement in the quality of the odor. To satisfy the full chlorine demand of these wastes, we estimate that 13,600 lbs per day of chlorine would be required, at an estimated cost in excess of $200 per day. Even to provide 30% of the chlorine demand would be uneconomical treatment considering the fact that it has no significant effect upon the BOD. We do not recommend, therefore, in favor

of direct chlorination of settled main-drain wastes unless such treatment is later found to be imperative to modify the sulfite odor or to kill coliform organisms in the mill sewage which enters the ditch.

Activated Sludge Studies

Data relative to the effectiveness of biological treatment in removing BOD and dissolved volatile solids from pulp and paper-mill wastes are very sparse in the literature. The results which have been published refer generally to concentrated digester liquors and not to relatively weak waste such as that in the main ditch. The fact that the river does such a marvelous job of stabilizing the wastes, primarily by biological action, points to the fact that comparable biological stabilization can be accomplished in secondary treatment works. We have therefore investigated the effectiveness of two conventional methods of secondary treatment, namely the activated-sludge process and trickling filtration. For such an investigation we found it necessary to set up and operate pilot plants, as described below.

A diagrammatic sketch of the apparatus used for the activated-sludge studies is shown in Fig. 21. To develop an activated sludge, slime was scraped from the rocks in the Clarion River about three miles below Johnsonburg and a mixture of this slime and settled main-drain wastes was aerated in the inverted Erlenmeyer flask shown in Fig. 21. At 4 to 8-hour intervals the compressed air was stopped, the sludge allowed to settle for 30 minutes, and the supernatant decanted; then a fresh load of waste was added and aeration was begun again. Loadings were varied by changing the aeration period within the range of 4 to 8 hours and by changing the suspended-solids content of the mixed liquor. After each change of loading, the unit was operated for about three days at the new loading before efficiency tests were conducted.

Inasmuch as paper-mill wastes are known to be highly deficient in nitrogen and phosphorous, we conducted a second set of efficiency tests with 8 ppm of nitrogen in the form of urea and 2.5 ppm of phosphorous in the form of Na_2HPO_4 being added to the raw waste. The sludge was given about a week to become adjusted to the new type of feeding, and then efficiency tests were run at various loadings.

The results of these activated-sludge tests are presented graphically in Fig. 22, which shows the per cent removal of BOD by activated-sludge aeration and secondary settling for various BOD load factors. In this figure, we have followed the method used in the National Research Council report on Army sewage treatment plants (Sewage Works Journal, September, 1946); and have included therein the results of the investigation made by the National Research Council on municipal sewage plants. The plot shows that the efficiency of BOD removal by activated-sludge treatment, without nutrients, is extremely low, much poorer than that of municipal plants with or without industrial wastes. When we added the nutrients, however, efficiencies comparable to those of municipal plants were attained. These experiments indicate rather conclusively that settled main-drain waste is amenable to biological stabilization by the activated-sludge process, but only when such wastes are fortified with nitrogen and phosphorous.

Logan and Heukelekian (Sewage Works Journal, March, 1948) studied the effect of aeration and resultant slime growths on strong SWL obtained by diluting Clarion Extract. First they applied just enough air to prevent

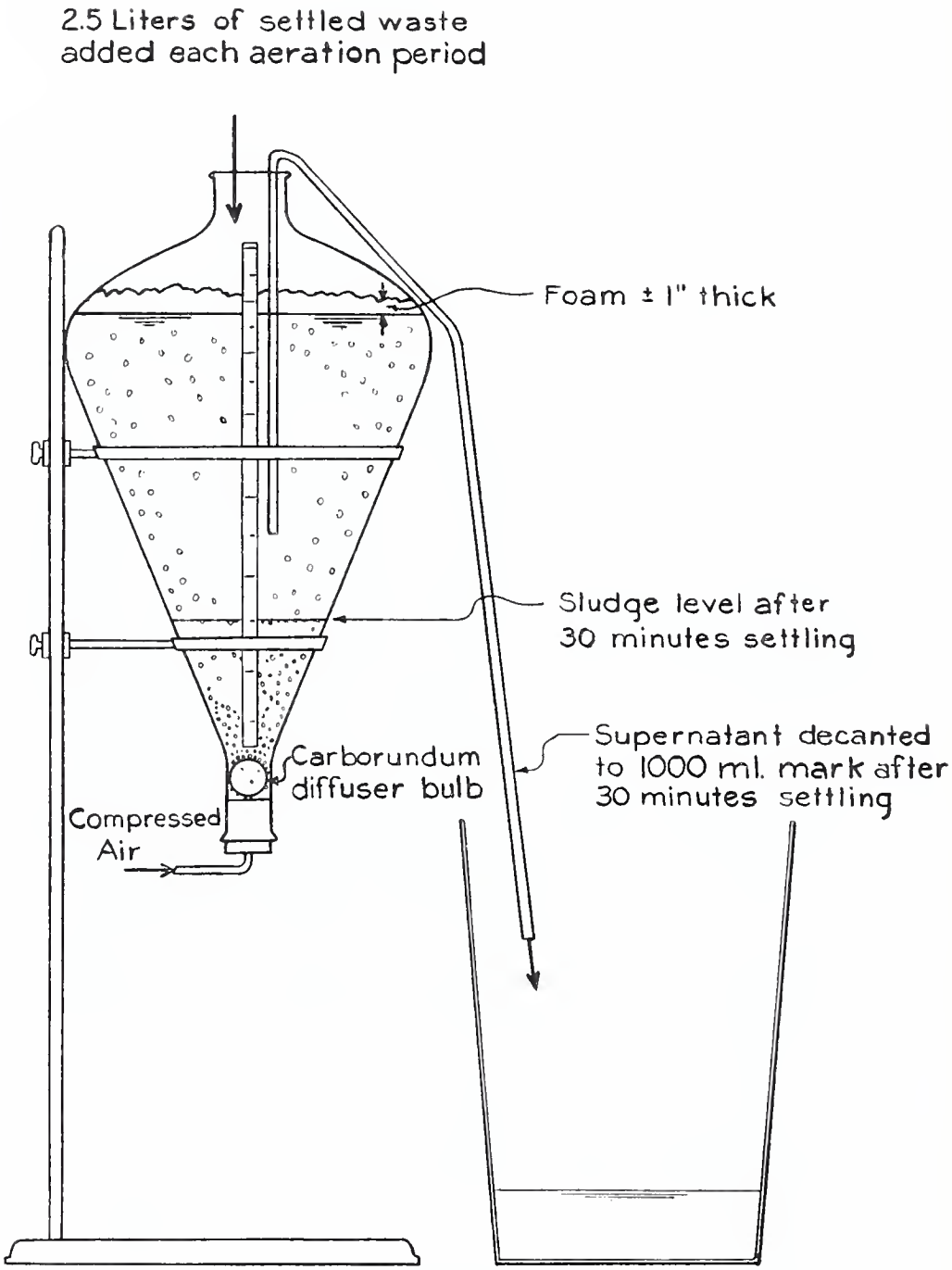

FIGURE 21.

DIAGRAMMATIC SKETCH OF APPARATUS USED FOR ACTIVATED-SLUDGE STUDIES

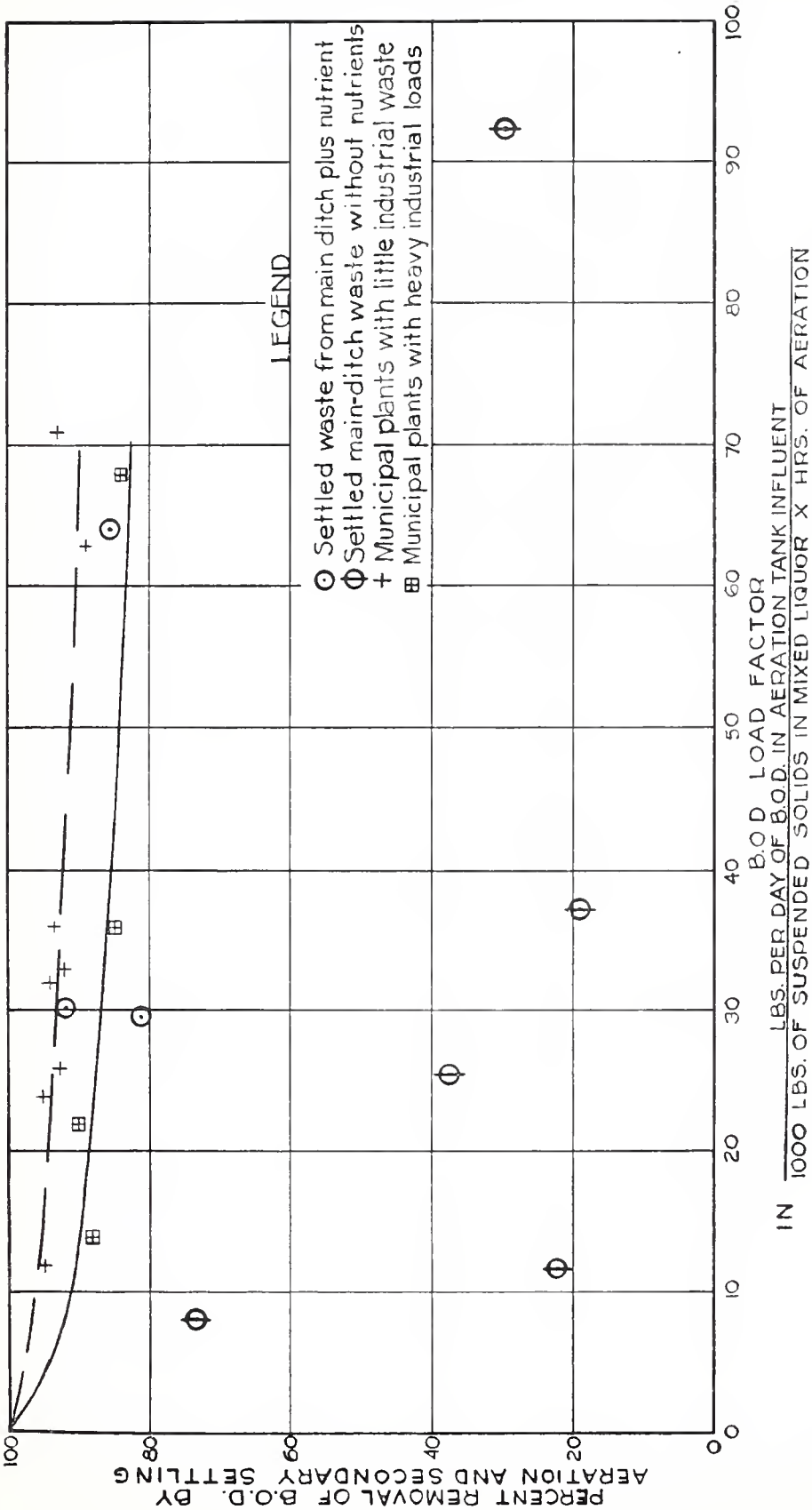

FIGURE 22.

RELATION BETWEEN EFFICIENCY AND LOADING OF ACTIVATED-SLUDGE AERATION TANKS

(After S.W.J., Sept. 1946, P. 105)

excessive foaming and on the full-strength wastes they obtained an average BOD reduction of about 22.6%. On wastes having a strength of 7,300 ppm of 5-day BOD, they obtained an average reduction of 26.7%. Even with pure-oxygen aeration and heavy feeding, the maximum BOD reduction was only between 30 and 35%. It follows, therefore, that their data corrobate our results as shown in Fig. 22 for main-drain wastes without nutrients, despite the fact that the BOD of our samples was only in the magnitude of about 400 ppm as compared with their very high BOD values. Logan and Heukelekian also studied foam-phase treatment, i.e. they allowed foam to build up to over ten times the volume of the liquid, and determined BOD removals in this foam. This treatment formed a tough biological slime which effected BOD removals as high as 60% in four hours of aeration, even with concentrated SWL. Sawyer (Industrial and Engineering Chemistry, November, 1940) found that SWL was amenable to activated-sludge treatment in concentrations up to 1,400 ppm of 5-day BOD, with proper nutrients. These data by other investigators bear out our results and point to the fact that main-drain wastes and weak SWL are amenable to activated-sludge treatment under controlled conditions with nutrients.

Experimental Trickling Filter

A diagrammatic sketch of the experimental trickling-filter plant is presented in Fig. 23. Settled main-drain waste was fed through a constant-head device onto a trickling filter 4 inches in diameter and 3 ft deep filled with coarse gravel. Provision was made to recirculate the settled effluent through another constant-head device onto the filter at a controlled rate. The filter was originally seeded with slime scraped from the rocks along the Clarion River about three miles below Johnsonburg. The loadings on the filter were varied by changing the rates of feeding of raw wastes and recirculated wastes. After each change in loading, the unit was operated for three days or longer at the new load before analyses of the influent and effluent were made to determine the efficiency of BOD removal. Experiments were first conducted with the settled main-drain wastes as obtained from the effluent end of the primary settling tank at Johnsonburg, and then the tests were repeated with wastes fortified with 8 ppm of nitrogen in the form of urea and 2.5 ppm of phosphorous in the form of Na_2HPO_4.

The results of these experiments have been plotted on Fig. 24, in accordance with parameters used by the National Research Council (Sewage Works Journal, September, 1946), together with the results obtained by the National Research Council on Army sewage treatment plants. The filter loading is expressed in thousands of lbs of BOD per equivalent acre foot. The equivalent acre feet is the actual volume of the filters in acre feet multiplied by a factor F, which in turn is related to the recirculation ratio (see reference). Fig. 24 shows that, without nutrients, the efficiency of BOD removal by filtration and secondary settling was in the magnitude of only 30 to 40%. With adequate nutrients, however, BOD removals comparable with those obtained in Army camps and municipal plants were achieved. No attempt was made to determine the effect of decreasing nutrient concentrations upon the percentage of BOD removal, the concentrations used being those recommended by C. N. Sawyer as a result of other experiments conducted by him.

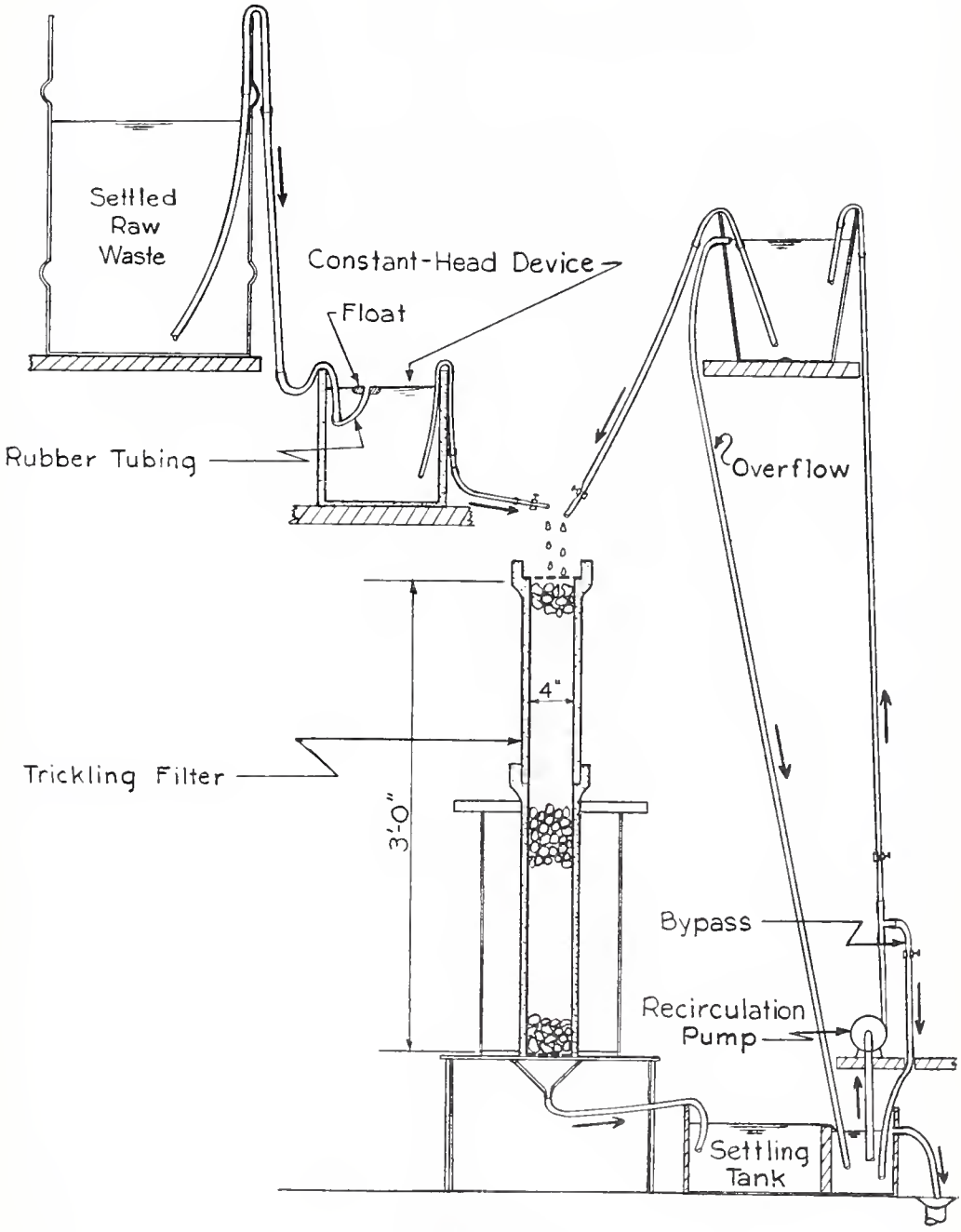

FIGURE 23.

DIAGRAMMATIC SKETCH OF EXPERIMENTAL TRICKLING-FILTER PLANT

Holderby (Sewage Works Journal, July, 1946) treated diluted strong SWL on a trickling filter similar to our pilot plant. He found that SWL dilutions having BOD values up to 3,730 ppm could be successfully treated to remove better than 95% of the applied BOD at loadings in excess of 6 lbs per cu yd per day, when the recirculation ratio was 15 to 1, with am-

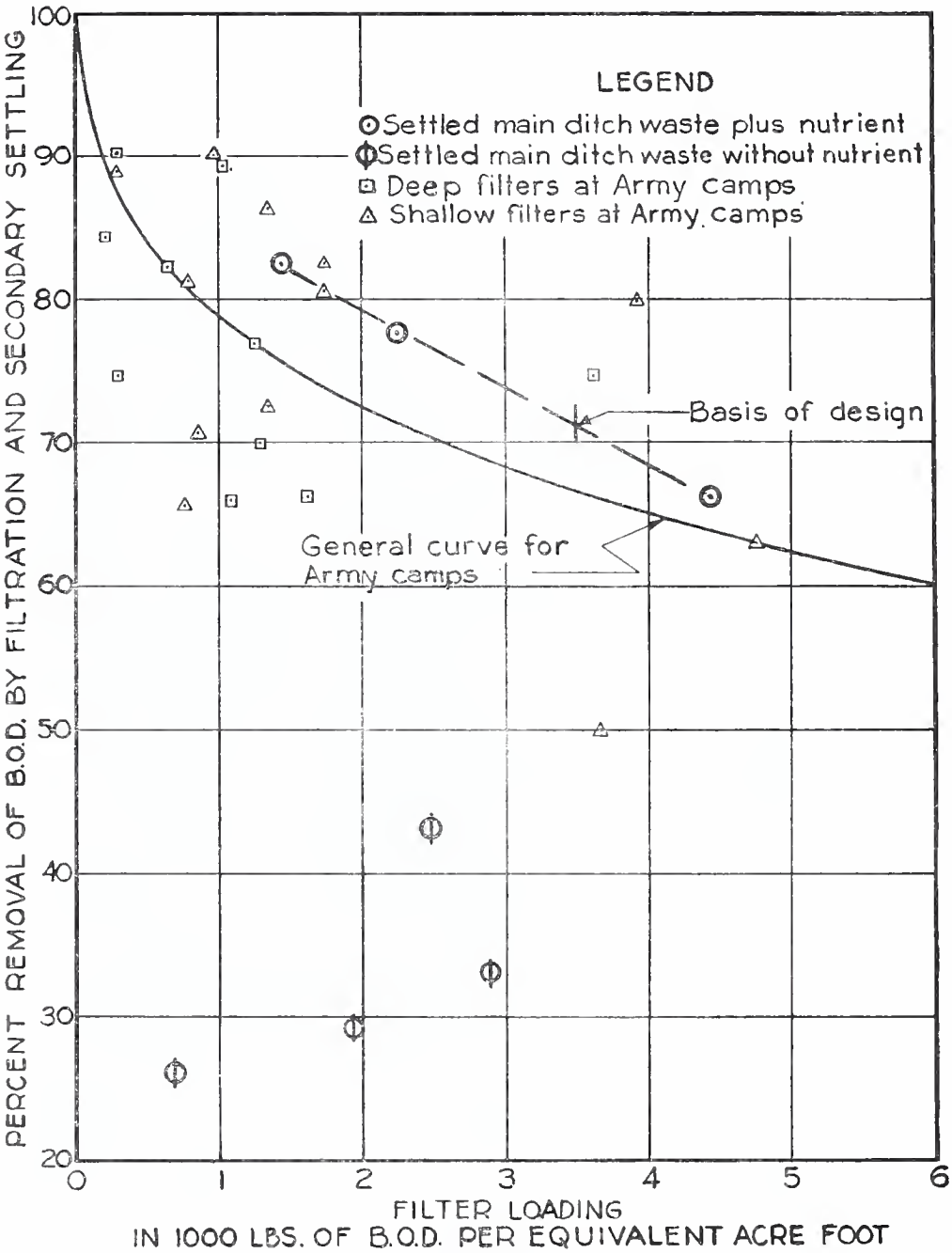

FIGURE 24.

RELATION BETWEEN EFFICIENCY AND LOADING OF HIGH-RATE TRICKLING FILTERS WITH RECIRCULATION

(After S.W.J., Sept. 1946, P. 965)

monium chloride and tri-sodium phosphate for nutrients. His loading of 6 lbs of BOD per cu yd per day at a recirculation ratio of 15 to 1 corresponds to a filter loading of 3,500 lbs of BOD per equivalent acre foot on Fig. 24. It is seen, therefore, that Holderby's results are even better than those obtained in our pilot plant tests. We conclude, therefore, that main-drain wastes and weak SWL are amenable to secondary biological treatment by high-rate trickling filters.

For secondary treatment of the main-drain wastes, high-rate trickling filters are preferable to the activated-sludge process for several reasons: (a) with a high rate of recirculation, trickling filters are less subject to disturbance by shock loads of strong SWL which are apt to be discharged into the main ditch than is the highly sensitive activated-sludge process; (b) foaming did not occur in our experimental trickling filter and apparently not in Holderby's experiments, whereas foaming in the activated-sludge process may be troublesome in the event that a batch of strong SWL reaches the plant; (c) the organisms associated with stabilization of these pulp and paper wastes, according to Logan and Heukelekian as well as our own observations, appear to function very well on attached surfaces and tend to build up better on such surfaces than in suspended sludges; and (d) trickling filters would probably produce a denser sludge than the activated-sludge process, thereby facilitating disposal to the Dill Hill lagoon. In the event that it becomes necessary to adopt secondary biological treatment of the main-drain wastes at Johnsonburg, we favor the use of high-rate trickling filters.

Alternate Corrective Measures: Their Effectiveness and Cost

Having established the sources, quantities and strengths of the various wastes and their characteristics with regard to treatment, we next investigated the effectiveness and cost of several alternate schemes of abating the pollution caused by such wastes. We have classified these alternate schemes into five primary cases and three proposed plans, as shown in Table 20.

For the BOD loadings given in Table 20 we have computed the theoretical oxygen balances in the river below Johnsonburg, based on the methods and factors described in Chapter III, at drought flow under present hydrometric conditions and at drought flow plus 72 cfs from the East Branch dam. All computations have been made for water temperatures at 25°C, which frequently obtained in the river during July and August. The reaction rates

TABLE 20

ALTERNATE CASES OF BOD LOADINGS AT THE NEW YORK AND PENNSYLVANIA COMPANY'S JOHNSONBURG MILL

Case	*Conditions of BOD Loadings at the New York and Pennsylvania Company*
A	Loadings in the river at the Grant St. bridge as they have existed during the average of the river surveys. This case represents very heavy loading from excessive overflows in the soda mill, with no displacement washing or other recent improvements in treatment. (5-day, 20°C BOD = 77,800 lbs/day)
B	Loadings based on our surveys of the drains and ditches, with the elimination of all pollution from soda-mill wastes and white waters, and 12% removal of main-ditch BOD by settling tanks. This case presupposes the complete

elimination of all overflow, breakdown and cleanup wastes.
(5-day, 20°C BOD = 36,800 lbs/day)

C Loadings based on our surveys of the drains and ditches, with the elimination of all pollution from soda-mill wastes, white waters, and overflow, breakdown and cleanup wastes, plus the elimination of one-half of the BOD in the main ditch by displacement washing and the removal of 20% of the remaining BOD by sedimentation. This case is essentially what the Company is doing or proposes to do.
(5-day, 20°C BOD = 17,000 lbs/day)

C' Same as Case C, but with the assumption that the immediate oxygen demand of the main-drain wastes is satisfied by chlorination or aeration.
(5-day, 20°C BOD = 17,000 lbs/day)

D-1 Same as Case C, but with efficient counter-current washing in the sulfite mill. This case is Plan I.
(5-day, 20°C BOD = 7,000 lbs/day)

D-2 Same as Case D-1, but with secondary biological treatment in lieu of the efficient counter-current sulfite wash. This case is Plan II.
(5-day, 20°C BOD = 7,000 lbs/day)

E Same as Case D-1, but followed by biological treatment and post-aeration of the main-ditch wastes so as to raise the dissolved-oxygen content of the effluent to 4.0 ppm. This case is Plan III.
(5-day, 20°C BOD = 3,000 lbs/day)

TABLE 20-A

The values of k_3 have been reduced about in proportion to the expected reduction in settleable and potentially settleable organic matter.
The values of the stream constants which were taken for each case are shown in the following table.

VALUES OF STREAM CONSTANTS

Case	*Stream Constants @ 20°C* k_1	k_3	k_r	k_2
A	0.13(1) 0.15(2) 0.18(3) 0.18(6) 0.18(7)	0.84(1) 0.19(2) 0.10(3) 0.01(6) 0.01(7)	0.97(1) 0.34(2) 0.28(3) 0.19(6) 0.19(7)	3.0(1) 3.0(2) 3.0(4) 1.4(5) 0.8(6) 0.5(7)
B	Same as A	0.20(1) 0.15(2) 0.10(3) 0.01(6) 0.01(7)	0.33(1) 0.30(2) 0.28(3) 0.19(6) 0.19(7)	Same as A
C & C1	Same as A	Same as B	Same as B	Same as A
D-1 & D-2	Same as A	0.15(1) 0.13(2) 0.10(3) 0.01(6) 0.01(7)	0.28(1) 0.28(2) 0.28(3) 0.19(6) 0.19(7)	Same as A
E	Same as A	Same as D-1 and D-2	Same as D-1 and D-2	Same as A

(1) Grant Street Bridge to below Johnsonburg
(2) Below Johnsonburg to Riley Run
(3) Riley Run to Toby Creek
(4) Riley Run to Ridgway
(5) Ridgway to Toby Creek
(6) Toby Creek to Millstone
(7) Millstone to Cooksburg

of deoxygenation and reaeration (k_1, k_2 and k_3) established in Chapter III have been used in these investigations, with proper adjustment of k_3 in each case to compensate for the degree of treatment to be achieved at the mill. See Table 20A.

At other points along the river the 5-day BOD loadings, applicable to all cases, have been taken as follows:

Borough of Johnsonburg's sewage:	600 lbs per day
Riley Run:	1,240 lbs per day when water is plentiful and
	930 lbs per day during droughts
Borough of Ridgway's sewage:	720 lbs per day
Eagle Valley Tannery at Ridgway:	1,350 lbs per day
Diluting tributaries:	2.0 ppm

The results of these computations are presented graphically in Fig. 25 for drought-flow conditions without dilution from the East Branch dam and in Fig. 26 for the same flows plus 72 cfs from the dam. Without the dam it is seen that all of the measures taken, or proposed to be taken, by the Company (Case C) will result in an anaerobic stretch of stream for about five miles below Johnsonburg and that not until the B. & O. Railroad bridge above Toby Creek is passed will the dissolved-oxygen content exceed the allowable minimum of 4 ppm. Even with highly efficient counter-current flow in the sulfite process (Case D), the river will not meet the proposed water quality standards for the first four or five miles below Johnsonburg, mainly because the entire drought flow of the East and West Branches will be passed through the mills and be depleted of oxygen. Hence, without the East Branch dam Case E becomes necessary if the entire river is to be reclaimed. If the Sanitary Water Board adopts the policy that the New York and Pennsylvania Company should be given no credit or allowances for this dam, then the high degree of treatment described hereinafter for Case E (Plan III) will be required.

Effect of Glen Hazel Dam

With the dilution provided by the East Branch dam, Fig. 26 shows that all of the measures taken, or proposed to be taken, by the Company (Case C) will not be adequate to prevent the oxygen content of the river from falling below 4 ppm below Johnsonburg and again below Ridgway. Even with post-chlorination of the settling tank effluent to oxidize the sulfites and so reduce the immediate oxygen demand (Case C') the oxygen content will sag below 4 ppm. Highly efficient counter-current washing in the sulfite mill (Case D-1) or, in lieu thereof, secondary biological treatment of main-drain wastes by high-rate trickling filters (Case D-2) will allow the dissolved-oxygen content of the stream to remain above 5 ppm throughout its length (Curve D on Fig. 26). Hence, with the East Branch dam, the high degree of treatment described in Case E will not be necessary. In view of the fact that the East Branch dam is actually under construction and will probably be completed within five years, we recommend that the New York and Pennsylvania Company be required to meet only the degree of treatment described in Cases D-1 or D-2 (Plans I or II).

Two questions arise in connection with the oxygen-balance studies de-

picted in Figs. 25 and 26: (a) what will happen to the oxygen content at other stream flows, such as ordinary low flows, and (b) what will happen if the contemplated dam is built on the lower Clarion River near Mill Creek? Let us first consider stream flows somewhat higher than drought flows. Increased flows will have two principal effects: (1) they will provide dilution which will lower the concentration of BOD in the stream and minimize the oxygen sag in upstream reaches, and (2) they will increase velocities in the stream, thereby transporting some of the BOD load to lower reaches and keeping the dissolved-oxygen content depressed for a longer distance. Hence, while dilution may help the dissolved-oxygen balance in upstream reaches it forces the load into lower reaches and causes a heavier loading in Piney Reservoir or in the contemplated new reservoir. Insofar as the minimum dissolved-oxygen content is concerned, we consider drought flow to be the most critical condition and have so based our conclusions.

The Proposed Dam at Mill Creek

The matter of a contemplated dam on the lower Clarion River and its effect upon the oxygen balance in the stream deserves most serious consideration. The lower Clarion River has long been considered an ideal stretch of stream upon which to construct a reservoir for flood control and low-flow regulation inasmuch as there are no sizable communities, no railroads and no important highways along the banks of the river between Mill Creek and Toby Creek. In fact, the Pittsburgh Flood Commission Report of 1911 stated that a reservoir constructed on the Clarion River near Mill Creek would have the lowest cost per mg of storage of any proposed reservoir in the entire Allegheny River basin. Despite the seemingly favorable conditions, such a reservoir has never been built primarily because the excessive pollution in the river would make the water in such a reservoir anaerobic and it has been feared that the reservoir would degrade the quality of the river water discharged into the Allegheny River so as to cause excessive taste and odors in the Pittsburgh water supply.

The U. S. Engineer Department is now considering a multiple-purpose dam to be located on the Clarion River near the mouth of Mill Creek. The maximum summer pool of the reservoir behind this dam would be at elevation 1,316 and would extend as far upstream as the mouth of Toby Creek. We have calculated the effect of such a reservoir on the oxygen balances in the stream for the same stream flow conditions described hereinbefore. The results of these calculations are shown by broken lines on Fig. 25 and Fig. 26. In these calculations, we used a negative k_3 value of 0.03 per day to allow for a certain amount of sludge deposit which will accumulate on the bottom of the reservoir (in Piney Reservoir, we found k_3 to be —0.095 to —0.106). We assumed, furthermore, that the reaeration rate, k_2, would be comparable to that in Piney Reservoir for the same depth and that the rate would vary inversely with the depth of the reservoir. The broken lines on Fig. 26 show that in Case C the dissolved-oxygen content in the reservoir would again sag below 4.0 ppm, whereas with Case D the sag in the reservoir would not be critical. Without the East Branch dam and with drought flows, Fig. 25 shows that the sags in the reservoir are not critical. This anomaly exists because much of the organic matter in the stream will be stabilized before the water reaches Toby Creek during drought flows. In other words, the oxygen sag in the proposed reservoir will be worse when

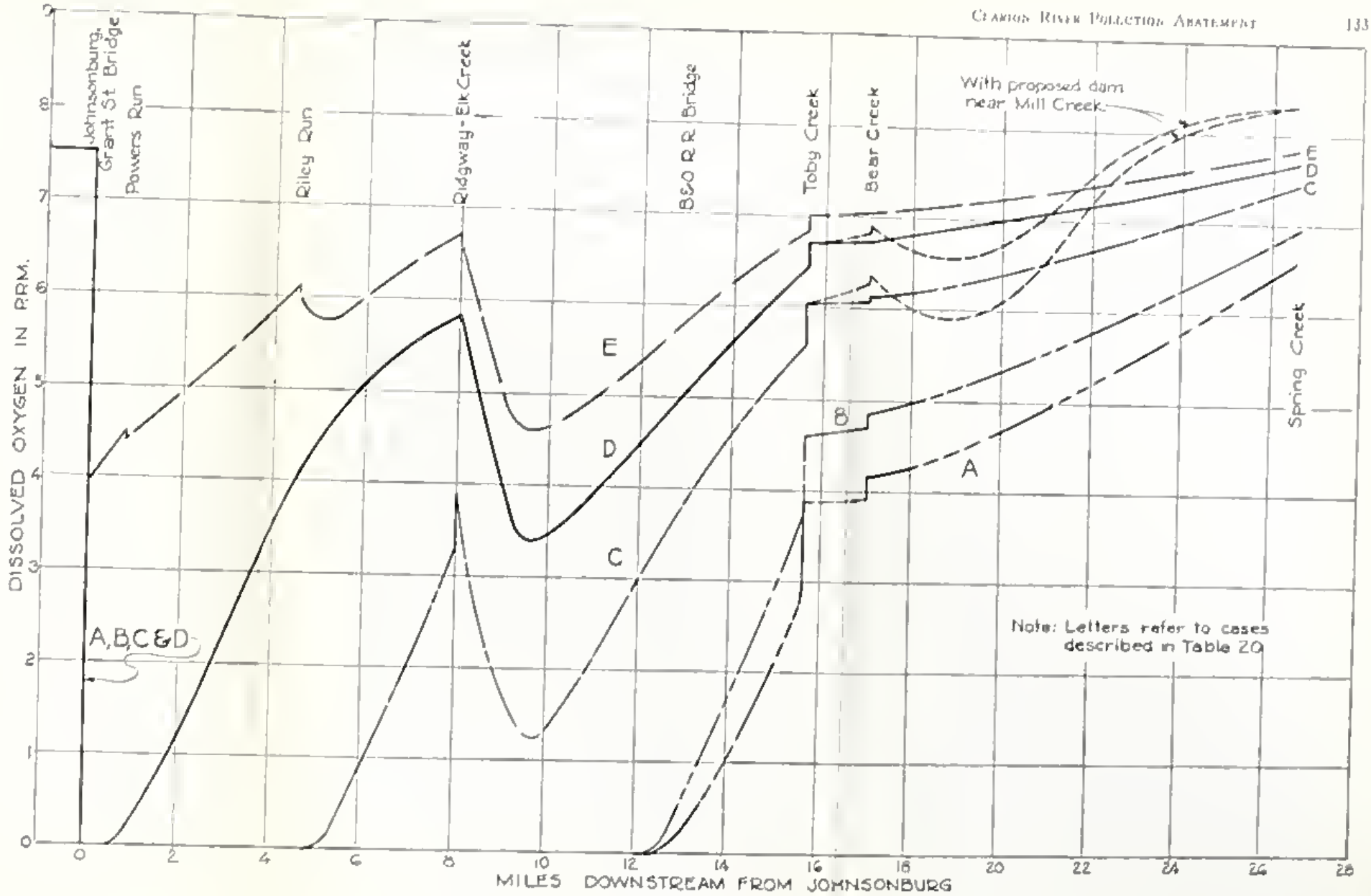

FIGURE 25. CALCULATED OXYGEN BALANCES FOR DROUGHT FLOWS WITHOUT EAST BRANCH DAM

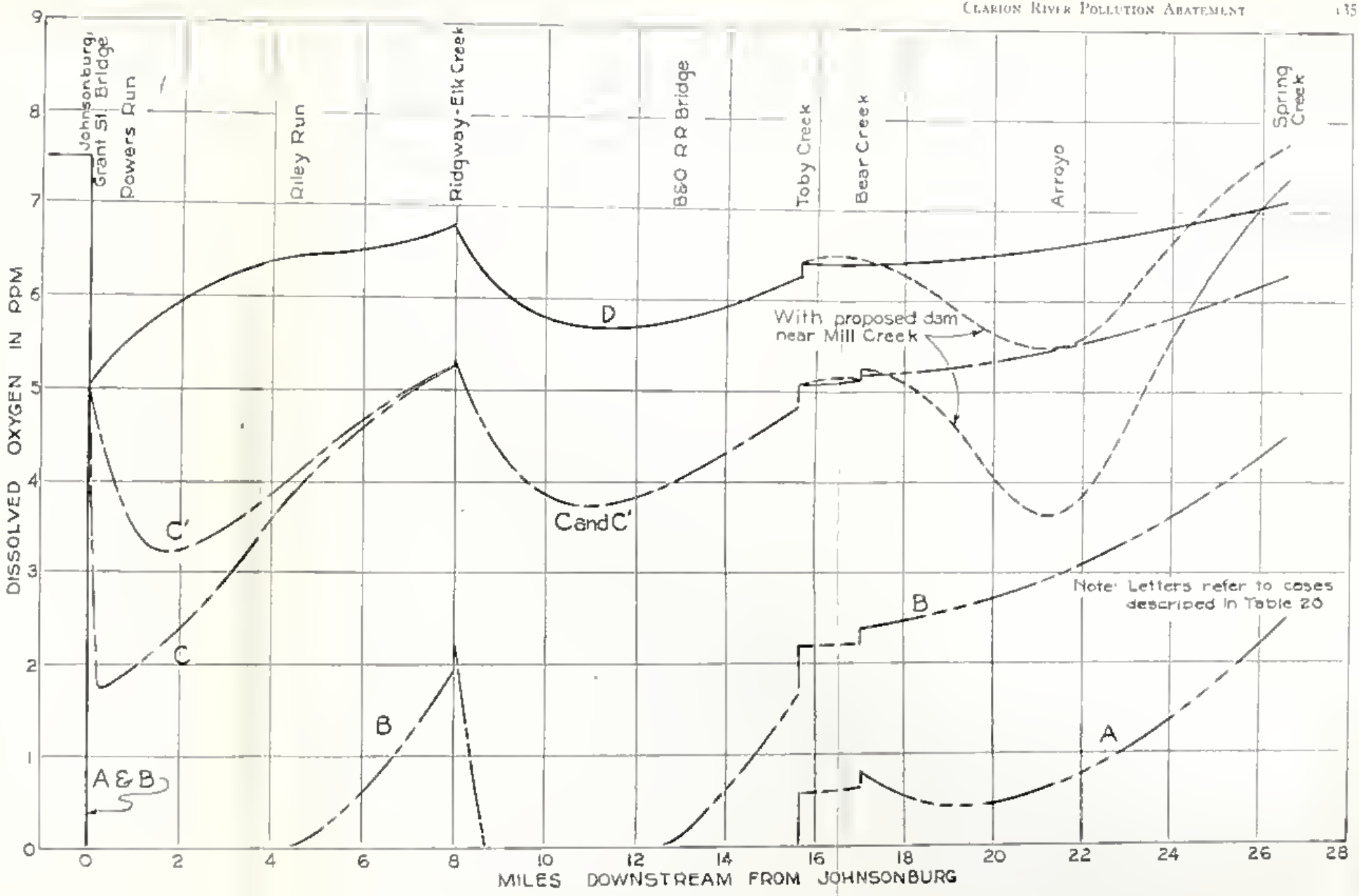

FIGURE 26. CALCULATED OXYGEN BALANCES FOR DROUGHT FLOWS WITH EAST BRANCH DAM.

there is dilution from the East Branch dam than without such dilution.

We conclude from these studies that the construction of the contemplated dam at Mill Creek will not seriously degrade the quality of the water in the Clarion River provided that such water is not polluted sufficiently at upstream points to cause the oxygen concentration to drop below 4.0 ppm at any upstream point. Until abatement to the extent of Case D is achieved, the construction of the contemplated dam is not recommended.

Plan I, Counter-Current Washing of Sulfite Pulp

The basis for Case D-1 as listed in Table 20 is efficient counter-current washing in the sulfite process. Let us now examine such a plan and its ramifications. Table 19 shows that, even with the present displacement washing method in operation, about 46% of the BOD in the main drain comes from weak SWL, about 11% from the subsequent stage in washing (the Oliver washer) and about 6% from the Oliver thickeners, or a total of 63% from all washing operations. If the present displacement washing system were replaced with a counter-current washer such as that shown in Fig. 14, we estimate that 95% of the BOD and dissolved solids in the sulfite liquors could be removed and concentrated for evaporation, thereby reducing the 5-day BOD of the main ditch by about 60% or say conservatively by about 10,000 lbs per day. This reduction would be sufficient to decrease the BOD of the main-drain wastes after sedimentation and after other minor changes to about 7,000 lbs per day. Moreover, the foaming characteristics and odor would be minimized.

The cost of such an installation in the sulfite mill based on three 8 ft x 8 ft stainless-steel washers with two intermediate repulpers and one final repulper, three stainless-steel-clad liquor tanks, each 25 ft in diameter by 25 ft deep, stainless-steel piping and pumps and the necessary allowances for a new building or for modification of existing space is estimated to be $700,000 or more than twice the cost of the new Impco washer in the soda mill. The high cost is attributable to the need for stainless-steel surfaces throughout to preclude corrosion by the acid SWL.

Unfortunately we cannot recommend in favor of this installation at this time because aeration of the sulfite liquors causes formation of sulfates, the precipitation of calcium sulfate (gypsum) and coatings on the wire meshes of cylinders and interior surfaces of pipes and tanks. It is understood that one or more cylinder washers have been installed in sulfite mills at Gatineau, Quebec and Ogdensburg, New York and it is further understood that these installations are giving considerable trouble because of the calcium-sulfate clogging.

In lieu of a continuous counter-current washer we have investigated the feasibility of improving the present displacement washing system to accomplish substantially the same degree of SWL removal. With reference to Fig. 15 it is noted that weak SWL flows to the ditch when its specific gravity falls below 1.5° Baumé (corresponding roughly to a BOD of 7,000 ppm), and washing is continued until the effluent is almost clear water. To prevent the discharge of these liquors, we recommend that a third and fourth liquor tank be added to the system and that the weakest liquors be recovered for further washing. In effect this means that a third and fourth stage will be added to the present displacement washing system so as to prevent entirely the discharge of any SWL to the ditch. All clear water

then used for the final wash could be made to appear in the concentrated SWL sent to the extract plant. It is estimated that this multiple-stage washing will increase the volume of strong SWL from about 172,000 gpd at present to about 188,000 gpd, and require only about 43,000 gpd of clear water. It is furthermore estimated that the necessary tanks, pumps and piping will cost an additional $49,800 for a four-stage system. These estimated costs are based on January, 1949 prices and the use of new stainless-steel clad tanks of 47,000 gallons capacity. The additional annual cost of operation and maintenance is estimated at $850 per year.

Recommendations

This improvement in the sulfite washing process constitutes our primary recommendation in Plan I and we feel that the New York and Pennsylvania Company can develop this plan to the extent required to reduce the BOD load on the river to 7,000 lbs per day or less. Plan I is considerably less costly in construction and operation than the alternate plan described below.

Plan II, Treatment of Main-Drain Wastes

Plan II is an alternate recommendation involving secondary biological treatment of the main-drain wastes, to be carried out if the Company feels that it cannot improve its displacement washing system to accomplish substantially complete removal of weak SWL. The works recommended to effect the required degree of treatment are shown in Fig. 27 and the bases of their design are described below.

Loading	*Bases of Design* *With no Displacement Washing*	*With existing Displacement Washing*
Average rate of flow, mgd	12	12
Maximum rate of flow, mgd	15	15
Minimum rate of flow, mgd	8	8
pH	7.0	7.2
5-day BOD, lbs per day	40,000	27,000
Suspended solids, lbs per day	40,000	40,000
Methyl-orange alkalinity, lbs per day	16,000	16,000

It is estimated that the primary settling tanks will remove 70% of the suspended solids, 12% of the BOD and 26% of the methyl-orange alkalinity.

In this plan it is proposed to intercept the effluent from the primary settling tanks and convey it to a sump in the proposed pump and chemical building, there to add recirculated wastes and nutrients in the form of anhydrous ammonia (up to 1,400 lbs per day) and ammonium hydrogen phosphate, $(NH_4)_2HPO_4$ (up to 2,125 lbs per day). Ammonia will be delivered in tank cars on a new railroad siding and dosed by means of an ammonia flow meter. Phosphate will be delivered in 100-lb bags in carload lots on the siding, stored on the second floor of the building and dosed by means of dry chemical feeders. The combined wastes will then be lifted to a distributing tower by means of five 7,500-gpm vertical axial-flow pumps (including one stand-by) capable of handling an average flow of 12 mgd

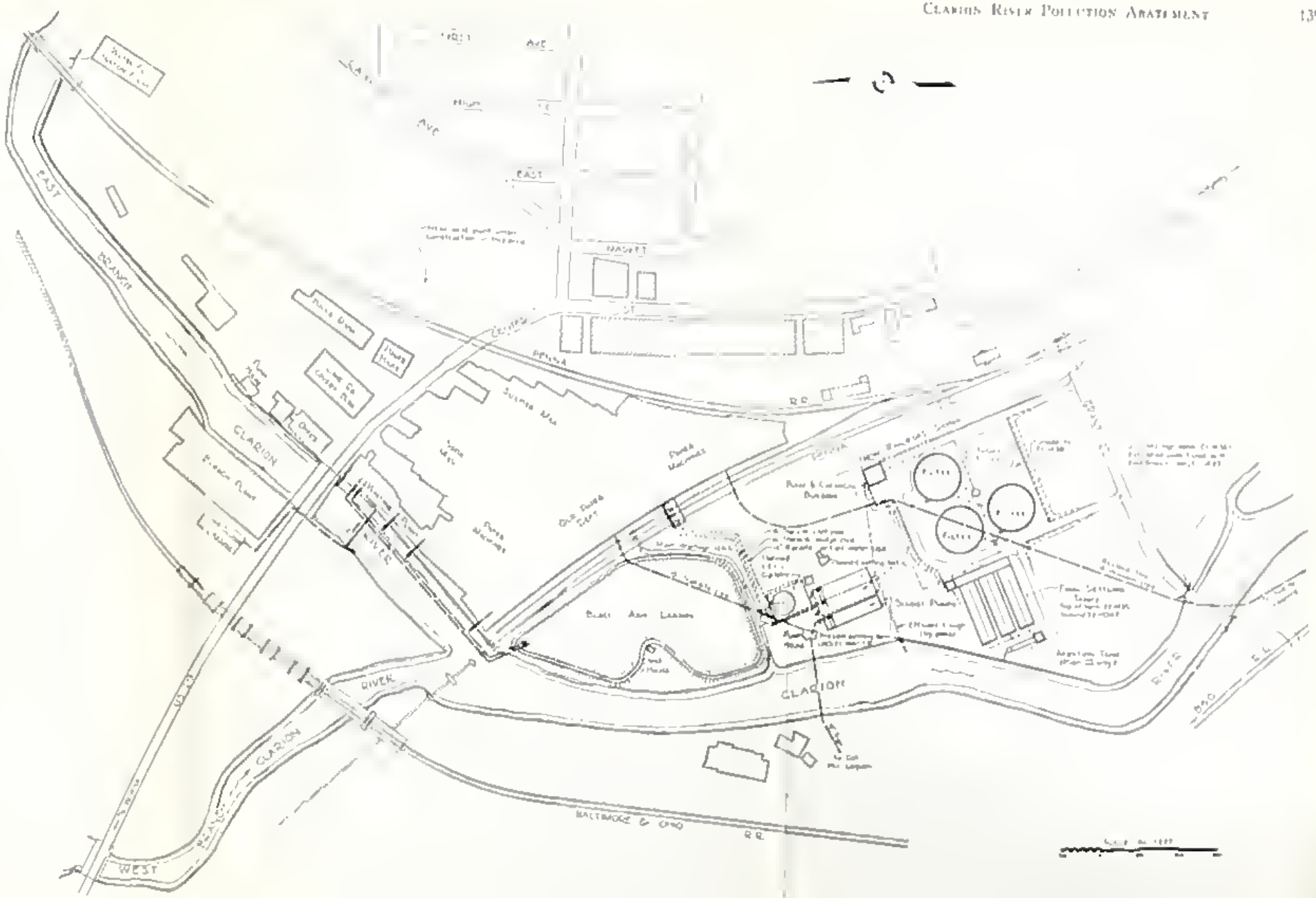

FIGURE 27. NEW YORK & PENNSYLVANIA COMPANY LAYOUT OF ALTERNATE SECONDARY TREATMENT WORKS.

with a recirculation ratio of 2.5 to 1. A high recirculation ratio is desirable in view of the variation in strength of the wastes in short periods of time. After the addition of anhydrous ammonia, it is probable that the pH of the mixture will exceed 8.5 and hence we have included in our estimate facilities for reduction of this pH by carbonation. Diffuser tubes will be installed in the distributing tower and flue gases from the combustion of oil or gas will be blown into the combined wastes before they are distributed to the high-rate trickling filters.

The filters will have capacity to remove about 72% of the applied BOD at a recirculation ratio of 2.5 to 1. Based on the above-listed BOD loadings and a loading factor of 3,500 lbs of BOD per equivalent acre foot (see Fig. 24), we estimate that three filters 120 ft in diameter with an average depth of 6 ft will be required with no displacement washing of sulfite pulp. If the present displacement washing system is continued in operation, only two such filters will be needed. The secondary settling tanks will consist of three units of double tanks with each pass 18 ft x 155 ft long x 6 ft average depth. The average overflow rate will be 800 gpd per sq ft and the average detention period 1.4 hours. Recirculation will be taken from a launder 15 ft from the influent end. Secondary sludge will be pumped to the influent end of the primary settling tank to be resettled with the primary wastes and then pumped to the Dill Hill lagoon. All structures are to be located above the maximum high-water elevation to be expected after the East Branch dam is completed.

Based on unit prices as of January, 1949, the estimated cost of construction of the secondary treatment works required for Plan II is $795,400, itemized as follows:

Pump and chemical building	$ 121,400
Trickling filters (3)	195,600
Secondary settling tanks	222,400
Yard piping and miscellaneous structures	54,900
Road and railroad siding	27,500
Grading and miscellaneous	41,000
Total	$ 662,800
Plus contingencies and engineering, 20%	132,600
Grand Total	$ 795,400

The annual operating costs are estimated as follows:

Chemicals, NH_3 and $(NH_4)_2HPO_4$	$ 86,500	per year
Electric power	15,000	" "
Additional personnel	6,000	" "
Maintenance at 1% of capital cost	7,900	" "
Total	$ 115,400	" "

With the present displacement washing system in operation it is probable that one of the filters can be eliminated, thereby reducing the construction cost about $50,000. The annual cost of operation and maintenance would then be reduced about $30,000 per year. If it becomes necessary to adopt secondary biological treatment, we suggest that the present displacement washing system be continued in operation.

Recommendations

We recommend against Plan II for the following reasons: (a) the high initial cost as compared to improvements in the displacement washing system, (b) the extremely high annual cost of operation and maintenance, attributable mostly to the nutrient chemicals, (c) the added burden of sludge in Dill Hill lagoon, which will further decrease its useful life, (d) the possibility that a slug of concentrated wastes would disrupt filter efficiency and (e) the lack of any income from salable by-products. This plan should only be used as an alternate in the event that the Company's efforts to improve its displacement washing system are not successful.

Plan III, Secondary Treatment Following Plan I

We have considered a third plan of high-degree treatment which will be required if credit is not given for dilution from the East Branch dam, i.e. Case E on Fig. 25. In that event, it will be necessary to reduce the 5-day BOD of the final effluent discharged to the river to 3,000 lbs per day (see Table 20), of which we estimate that 540 lbs will come from the Swenson evaporator drain. In this plan we propose that efficient displacement washing in the sulfite mill (Plan I) be supplemented by a secondary treatment works to remove 72% of the BOD which will remain in the main ditch despite almost complete removal of SWL. The hydraulic features of the required plant would be quite similar to those described above, but the size of the three filters need be only 95 ft in diameter and 3½ ft deep, with a recirculation ratio of 1.05 to 1. Four 6,000-gpm pumps would be used, of which one would be a stand-by. Corresponding reductions would be made in the quantities of chemicals used and in electrical power. However, it would be necessary to aerate the effluent from the secondary settling tanks so as to provide a minimum of 4.0 ppm of dissolved oxygen in the effluent discharged to the stream.

We estimate the cost of the secondary treatment works in Plan III to be $651,000, itemized as follows:

Pump and chemical building	$ 93,200
Trickling filters	106,400
Secondary settling tanks	221,000
Aeration tank and blowers	10,900
Yard piping and miscellaneous structures	48,500
Roads and railroad siding	27,500
Grading and miscellaneous	35,000
Total	$ 542,500
Contingencies and engineering, 20%	108,500
Grand Total	$ 651,000

The annual costs of operation and maintenance are estimated as follows:

Chemicals, NH_3 and $(NH_4)_2HPO_4$	$ 27,000	per year
Electric power	8,500	" "
Additional personnel	6,000	" "
Maintenance	6,500	" "
Total	$ 48,000	" "

Recommendations

We recommend against Plan III for many of the same reasons as given for Plan II and because we do not feel that this high degree of treatment is warranted if the East Branch dam is built.

Recommended Improvements Summarized

We recommend that Plan I be adopted and that as a part of that plan the Company construct two additional stages to its displacement washing system for sulfite pulp, estimated to cost $49,800. In the event that the operation of this plan is not successful enough to reduce the 5-day BOD load on the river to 7,000 lbs per day or less, we recommend that a high-rate trickling filter plant be built substantially as shown on Fig. 27.

In addition to the major problem of treating the main-drain wastes, there are several other requirements in Plan I which have been mentioned hereinbefore and for which we submit the following specific recommendations, with the estimated cost of construction and operation where such are significant. We recommend:

1. That the Swenson evaporator condensate continue to be discharged to the East Branch through drain D-8, but that all sanitary sewage be eliminated from this drain and piped to the borough's sanitary sewers or to the main ditch as described below.

2. That all sanitary sewage throughout the Company's property either be excluded from the mill drains and piped to the borough's sewers, or if the Company so prefers that all such sewage be discharged to the main ditch and that the entire main-ditch flow be chlorinated. We have made no attempt to estimate the cost of repiping to the borough's sewers because of the many details involved and because the plans will be influenced by the borough's plans for interceptors. We estimate the annual cost of chlorination to be $73,000. We recommend that commitments with regard to sanitary sewage be deferred until the borough takes action to intercept and treat its sewage and until other proposed improvements are completed and in operation. At such time the need for chlorination for odor abatement can also be better evaluated.

3. That the bleach-plant-basin effluent (D-16) continue to be discharged to the East Branch unless such discharge later proves toxic to aquatic life in the stream, in which case it should be pumped into the main drainage system.

4. That no action be taken at this time in regard to the whiting-plant drains, D-4 and D-7, in view of the announced plan for construction of a new whiting plant, from which there are to be no liquid wastes.

5. That a sump be constructed on the soda-mill drain (D-6) and that all miscellaneous soda-mill wastes be pumped into the main ditch. With the new Impco washer in service these wastes should be relatively weak, but as a precaution against possible slugs of strong wastes, this effluent should be combined with the main-drain wastes. The estimated cost of construction of the sump pump and pipeline is $6,300 and the annual pumping cost will be relatively small.

6. That the black-ash basin continue to be used until the entire matter of the effective combustion of Swenson evaporator liquor is resolved by the Company, that the Company be pressed to obtain an early solution of this

problem and that until such time the dewatered black ash be hauled from the basin by truck or by rail (236 cubic yards per day or about 48 truckloads per day) and dumped on abandoned land. Attempts should be made by the Company to intermix the black ash with the coal and burn it in the power plant. To facilitate hauling, the black-ash basin should be divided into two basins by a dike so that one basin can receive liquid waste while the other basin is being emptied of drained black ash. The initial investment for a drag-line, trucks, dike, and access roads is estimated at $46,000 and the annual cost of a three-mile haul by truck is estimated at $37,700, including operation, depreciation, interest and insurance.

7. That the overflow conduits between the Lancaster wash-water-effluent pipeline and the main drain be permanently blocked to prevent old-paper wastes and monosulfite filter cake from entering the river, and that a tank of about 300,000 gallons capacity be built near the Dill Hill pumping station to store temporary excesses of flow, or all flow during pump shut-downs. The cost of this tank and related piping is estimated at $30,500.

8. That the filter waste wash water and settling-tank sludge at the water treatment plant be excluded from the East Branch and in lieu thereof that they be collected in a one mg holding tank and discharged at a uniform rate through a 12-in. free-flowing sewer to the main ditch for further sedimentation in the new settling tanks. We estimate the construction cost of a pumping installation for unwatering the basins, a holding tank and the connecting sewer to be $55,400. Additional operating costs would be comparatively negligible.

9. That the Dill Hill lagoon continue to be used for old-paper wastes and calcium monosulfite filter cake, and that it be used as planned for primary-settling-tank sludge.

10. That the floor drainage and overflows of strong SWL in the extract plant be collected in a tank and recovered in the evaporators.

11. That the pipeline which conveys the Clarion Extract to the tank cars be drained into a similar tank for reclamation rather than into the main ditch.

12. That clean-up wastes in the extract plant be drained to the valley lagoon.

13. That the borough of Johnsonburg's storm drainage be excluded from the main ditch.

14. That extreme care be taken by the Company's authorities and by all workmen to prevent overflows and breakdowns from discharging slugs of strong wastes to the drains. Emergency holding tanks or alternate units should be installed where necessary to accept diverted liquors in case of breakdown.

GENERAL CHEMICAL DIVISION, ALLIED CHEMICAL AND DYE CORPORATION

Description

The aluminum-sulfate plant of the General Chemical Division, a subdivision of the Allied Chemical and Dye Corporation, is located at the confluence of Powers Run and the Clarion River about a mile below the pulp and paper mill. The existing plant was constructed in 1946 and it is understood that it produces liquid aluminum sulfate primarily for use at the

New York and Pennsylvania Company plant at Johnsonburg. The general layout of the plant and the waste disposal works is shown by Fig. 28.

There are two sources of industrial wastes at this plant: (a) the so-called "mud waters" and (b) floor drains and washings. The exact processes employed at the plant in the production of these wastes are reported to be secret, but it is understood that the mud waters contain quantities of acid, aluminum, iron, silicon, sulfate, sand and stones. The mud waters, floor drains and washings are discharged into two lagoons or mud ponds as shown on Fig. 28. These ponds have a total area of approximately 28,000 sq ft. The lagoons have no effluent pipes or drains, and since there is no overflow it is expected that all excess water is evaporated or leached into the surrounding soil. Our studies indicate that the mud ponds will probably not be flooded by floods of the magnitude of the 1942 flood after protection is available from the East Branch dam.

Approximately 6,000 lbs of mud water is pumped each week into the lagoon, pumping every other day, and lime is added to produce a precipitate. The solid material so formed hardens sufficiently to be walked on. It is understood that the Company intends to allow the lagoon to fill up with precipitate and then to remove the solid cake for use as fill or to dump it on waste land. Sanitary sewage from the plant is drained to a septic tank and into a sub-surface irrigation field as shown on Fig. 28.

Recommendations

Inasmuch as there are no liquid wastes from this plant which discharge into the Clarion River or its tributaries, we recommend that the present method of waste disposal be continued.

BOROUGH OF JOHNSONBURG

Description of Sewage Disposal

The surveys and analyses described in Chapter III show that the Clarion River is polluted with respect to sewage bacteria from the population of Johnsonburg and Rolfe. The extent of pollution by BOD, solids and other pollutants was masked by the heavy industrial load from the paper mill.

We have received conflicting reports relative to the status of sewerage and sewage disposal at Johnsonburg and Rolfe; but inasmuch as the details are of no great import for the purposes of this survey we have made no detailed study of the Johnsonburg sewerage situation. To the best of our knowledge, the following description represents the situation. It is understood that sewers were installed in 1908 and that, in general, sanitary sewers are separate from storm drains. Most of the borough's sanitary sewage is collected in one trunk main which discharges into Powers Run near its confluence with the Clarion River. There are, however, many small sewers which drain into the East Branch, the West Branch, or into Silver Creek in Rolfe. Almost all of the sewage from the pulp and paper mills is discharged with the industrial wastes. A large part of the sanitary sewage of Johnsonburg and Rolfe is not included in the main trunk sewer discharging into Powers Run. The U.S.P.H.S. analyses in 1940 showed bacterial concentrations at the Grant Street bridge almost as great as those below the mouth of Powers Run, which indicates that about two-thirds of

the sewage in the Johnsonburg area is discharged to the Clarion River or its branches upstream from the Grant Street bridge.

It is understood that in 1917 the town was ordered to provide primary treatment of its domestic sewage and at that time constructed a plant comprising a pumping station and bar screen along Powers Run and an Imhoff tank, chlorinator and sludge beds on the opposite bank of the Clarion River. Because of the excessive pollution of the paper mill, the treatment plant was not operated and has since been abandoned. In 1938 the borough of Johnsonburg submitted plans to the Sanitary Water Board for certain interceptors and sewage treatment works for which permits were issued subject to certain special conditions. These works have not been constructed. According to the Burgess the borough has not been issued a formal notice to treat its sewage or submit plans in recent years; but we have also been given to understand that the Sanitary Water Board issued a permit for sewage treatment works in 1943.

We have investigated the matter of sewage disposal at Johnsonburg with respect to the degree of treatment required, and have reached the following conclusion: if all sanitary sewage from the borough of Johnsonburg, including Rolfe, is collected and given primary treatment at a plant located near the mouth of Powers Run, the BOD loading of such sewage will not exceed the allowable increment of loading as shown in Table 13, provided of course that the paper mill does not exceed its allowable loading at the Grant Street bridge.

Insofar as BOD loading is concerned, therefore, secondary treatment of the borough's sewage is not necessary to maintain the water quality standards. As shown in Chapter III, however, over 99% of the coliform bacteria in the sewage must be killed to prevent bacterial pollution of the river during drought flows. To achieve this effectiveness of bacterial kill, it will be necessary to install primary treatment for the removal of coarse solids which cannot be effectively chlorinated and to chlorinate the final effluent. The removal of settleable solids and floating scum by primary sedimentation is also necessary to prevent formation of sludge banks and to meet esthetic standards.

Recommendations

We recommend that the borough of Johnsonburg collect all of the sewage from the numerous small outfalls, convey it to a site near the mouth of Powers Run and there provide primary treatment and chlorination of the effluent.

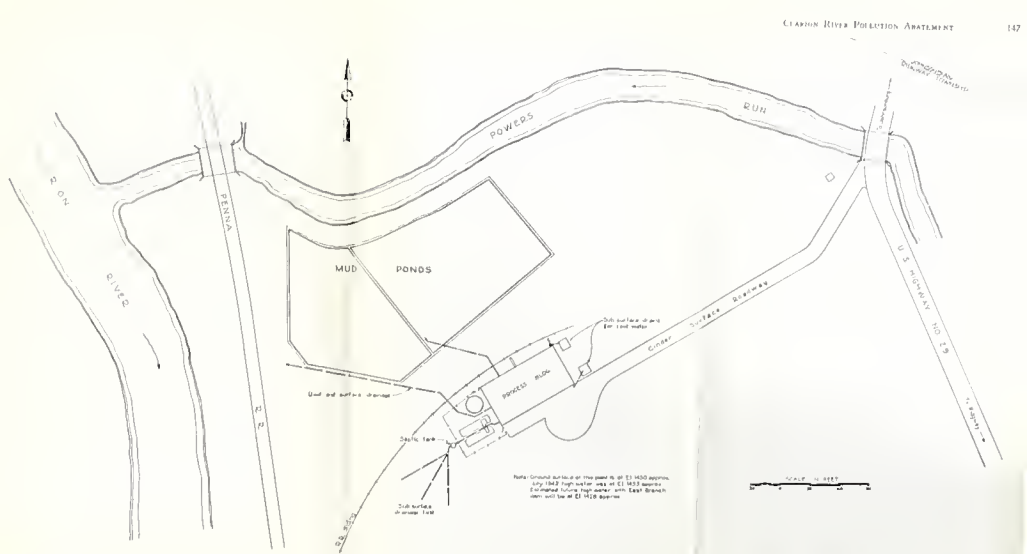

FIGURE 28. GENERAL CHEMICAL DIVISION, ALUMINUM SULFATE PLANT NEAR JOHNSONBURG, PA., EXISTING WASTE DISPOSAL WORKS.

CHAPTER VII.

ELK CREEK AT ST. MARYS

From the viewpoint of stream pollution, the borough of St. Marys occupies a difficult geographic position, being situated at the headwaters of Elk Creek where stream-flow dilution is practically non-existant. In addition to domestic sewage from the borough, the headwaters of Elk Creek receive liquid wastes from the Speer Carbon Company, the Stackpole Carbon Company, the Armour Leather Company, and the Straub Brewery. Another potential source of stream pollution is the St. Marys Meat Packing Company. There are other carbon companies in and near St. Marys, but our reconnaissance showed them to have no liquid wastes.

SPEER CARBON COMPANY

Description

As shown in Fig. 1, the Speer Carbon Company is located on the south branch of Elk Creek near U. S. Route 120. This plant manufactures several types of carbon electrodes and related products from carbon flour. It is understood that the present plant layout, shown in Fig. 29, is of a temporary nature and that engineers of the Speer Carbon Company have drawn up plans to expand the plant and relocate much of its present equipment and processes. Some of these changes are in the process of construction. Water for all purposes is obtained from the borough of St. Marys, and sanitary sewage is discharged to the borough's sewers.

There are three sources of waste waters which are discharged to Elk Creek at this plant: (a) periodic wash waters from cooling of the ovens, (b) soak waters for cooling of the oven-solidified carbon products, i.e., from electrode vats, and (c) washing and cleaning waters from the electrode-grinding machines. When the plant is finally remodelled, the first two sources of these wastes will be led by connecting pipes and ditches to a main trunk line and discharged into Elk Creek. At the present time these drains and ditches are being constructed. The wash waters from the oven carry a small amount of soot and grit. The water from the electrode vats is relatively clear and contains a small amount of oil and scale from the finished electrodes. Our investigation indicates that both of these wastes are of negligible importance as contributors to pollution. The third source of waste water contains fine carbon granules from the electrode-grinding process. In the present layout, there is one electrode-grinding machine in Plant No. 2 which uses 30 gpm of city water, and discharges into a new 22-in storm-water sewer, as shown in Fig. 29. At another location in Plant No. 2 there are five small grinding machines, three of which operate 8 hours per day, 5 days per week and use a total of about 90 gpm of recirculated water or make-up water from the borough's system. The seventh wet grinder is located in Plant No. 1, operates 7 hours per day for about 3 days per week and uses approximately 60 gpm of city water. The effluent from

this grinder joins the effluents from the group of five grinders and the combined flow is pumped to a treatment plant.

The present treatment works consist of a Hardinge circular clarifier, which employs the principle of flocculation and agglomeration by upward flow through a sludge slurry. The settling tank is 25 ft in diameter and has an effective depth from the top of the sludge blanket to the top of the effluent weir of 8 ft. For an average influent rate of 150 gpm, the settling tank provides an overflow rate of 440 gpd per sq ft. Sludge is collected by a scraping mechanism into a conical sump, from which a 30-gpm plunger pump lifts the sludge through a 4-in line to a truck which hauls it to a dump for land fill. Sludge is pumped for one or two short periods each day, depending upon the accumulation. A part of the settled effluent is discharged into a storage well from which it is pumped back to the five smaller grinders in Plant No. 2, and the remainder overflows to Elk Creek. Inasmuch as the Hardinge clarifier receives water from one 60-gpm grinder and three 30-gpm grinders, and returns water only to the smaller grinders, there is generally an overflow of about 60 gpm of clarified effluent from the treatment works into Elk Creek.

Analyses were made of the influent and effluent at the treatment works on October 27, 1948. The results of this survey are presented in Table 21 and show that the treatment plant was removing 97.3% of the total solids and 99.2% of the suspended solids. The actual removal, insofar as pollution abatement is involved, is even greater inasmuch as most of the effluent is returned to the grinders. It is to be noted from Table 21 that the BOD of these wastes is insignificant and that they are practically saturated with dissolved oxygen. The pH is near normal and the alkalinity is not excessive. We also sampled the water discharged from the electrode vats and found it to contain no significant quantities of pollutants, as shown by Table 21. At the time of our survey, however, one wet grinder was discharging approximately 30 gpm into the storm-water drain, thereby causing pollution of the south branch of Elk Creek by a strong concentration of fine carbon granules. It is understood that the Speer Carbon Company intends to divert the waste from this grinder into the regular system for treatment with the wastes from the other grinders.

The adequacy of the present treatment and the effect of the effluent from the Hardinge clarifier on the stream could not be determined at the time of our survey because the one grinder which discharged without treatment imparted a black discoloration to the stream, thereby masking the effect of the treatment plant effluent. The effluent from the clarifier had a grayish color and a moderate turbidity caused by the residual fine carbon granules, but we were not able to determine whether the effluent would produce objectionable color or turbidity in the stream.

Inasmuch as the stream is heavily polluted a short distance below the Speer Carbon Company by organic matter from the tannery and by a heavy load of carbon granules from the Stackpole Carbon Company, the slight concentration of carbon in the effluent from the Hardinge clarifier is of minor importance at the present time. In the future, however, when all organic pollution and direct wet-grinder discharges have been eliminated from Elk Creek within the borough limits, it may be found that the effluent from the clarifier contributes objectionable color to the stream. If this is

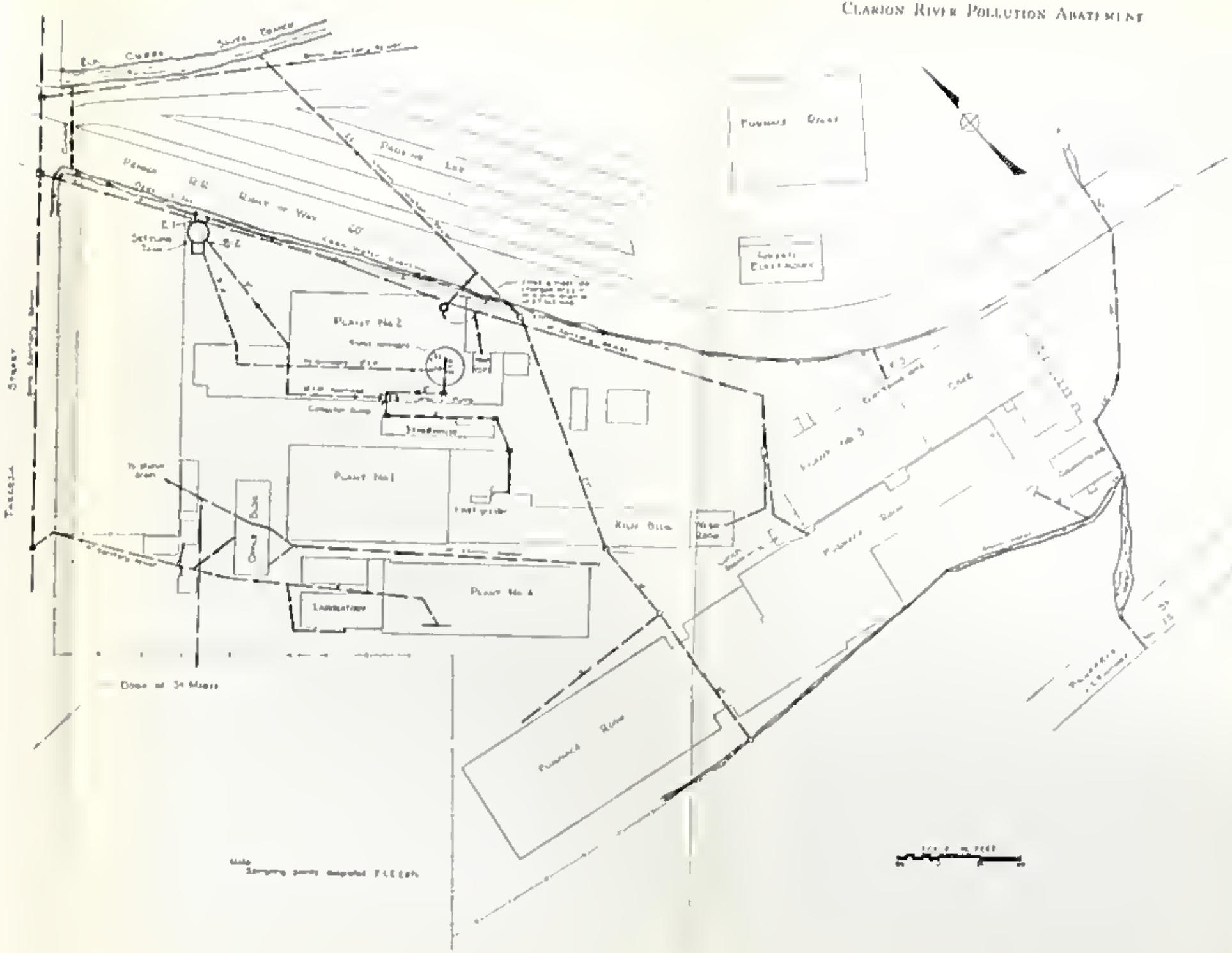

FIGURE 29. SPEER CARBON COMPANY EXISTING WASTE DISPOSAL WORKS.

TABLE 21. SPEER CARBON COMPANY, ST. MARYS, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED OCTOBER 27, 1948

Sampling Point	*Sample No.*	*Dissolved Oxygen* ppm	*5-day 20°C BOD* ppm	*Total Solids* ppm	*Suspended Solids* ppm	*Dissolved Solids* ppm	*pH*	*Alkalinity to pH 4.3 as $CaCO_3$* ppm	*Temp.* °C
Influent to Hardinge Clarifier.....	E-2	8.29	1.81	5883	5910	—	7.77	50	15
Overflow from Treatment Plant.....	E-1	9.55	0.48	148	52	96	7.57	64	15
Removal by Treatment Plant...			1.33*	5735*	5858*	—		—	
% Removal.....			73.5%*	97.3%*	99.2%*				
Waste from Electrode Vats.....	E-3	8.50	1.62	85	80	5	7.36	40	—

*Based on condition of all plant effluent discharging to stream. Actually, the effluent is usually recirculated for re-use in the grinding processes.

found to be the case, better removal of carbon granules may be obtained by recycling all the clarifier effluent, by the use of coagulating chemicals, by filtration of the clarifier effluent or by combinations of these procedures.

Recommendations

We recommend that the Speer Carbon Company carry out its plans to treat the waste from the one wet grinder which now discharges into the storm drain and that no further treatment of the clarified wastes be required unless it is found that the clarifier effluent contributes objectionable color or turbidity to the stream after other pollution at St. Marys has been abated.

STACKPOLE CARBON COMPANY

Description

The Stackpole Carbon Company is located at the confluence of the north and south branches of Elk Creek as shown in Fig. 1. The principal products of this plant are carbon electrodes and plates, the average monthly production being about 1.5 tons. The plant uses approximately 20,000 gpd of borough water, supplemented occasionally by a 250-gpm well on the premises. Sanitary wastes are discharged, for the most part, to the borough's sewer. The only significant liquid industrial wastes from this plant originate in the polishing and finishing operations where water is used as a lubricating agent. These wastes contain fine carbon particles, some carborundum and possibly some cutting oils.

Wastes from the wet grinding machines in the flashlight-electrode department are drained to an 8 ft x 8 ft sump 8 ft deep, equipped with four float-controlled 75-gpm centrifugal pumps, as shown in Fig. 30. Two of these pumps have been found to be superfluous, since no more than one of the pumps operates at a time and for normal operation it runs about five minutes and is off about seven minutes. The pump discharges into a 6-in pipeline leading to a new Link-Belt rectangular settling tank. This treatment plant, installed in 1947, was reported to be designed for 10,000 gallons per hour (167 gpm) at a 1.5-hour detention period. It was estimated that 19 cu ft of sludge would be produced per hour. The tank is 42 ft long, 8 ft wide and has an average depth of 6 ft. With one pump of the existing sump in operation, the overflow rate is 321 gpd per sq ft and the detention period is 3.35 hours. The carbon sludge which settles out in the tank is scraped by a continuous collection up an inclined surface and discharged into a trailer. The sludge so collected is hauled to a dumping area on the premises as shown by Fig. 30. The final effluent from the plant is discharged into a slough leading into Elk Creek.

Not all of the wet grinding machines are located in the flashlight-electrode department, and those which are situated in the metal-parts department discharge into drains which lead into Elk Creek, as shown in Fig. 30. We surveyed all of the drains along Elk Creek, and found that four of them discharged carbon granules either continuously or intermittently. The other drains were either storm-water sewers, roof drains, or effluent pipes containing cooling water or steam condensate. The Company has prepared plans to construct a sump betwen the metal-parts department and Elk Creek to collect the effluent from all of the grinding machines in this general area and to pump such wastes through a new 3-in force main into the existing 6-in line

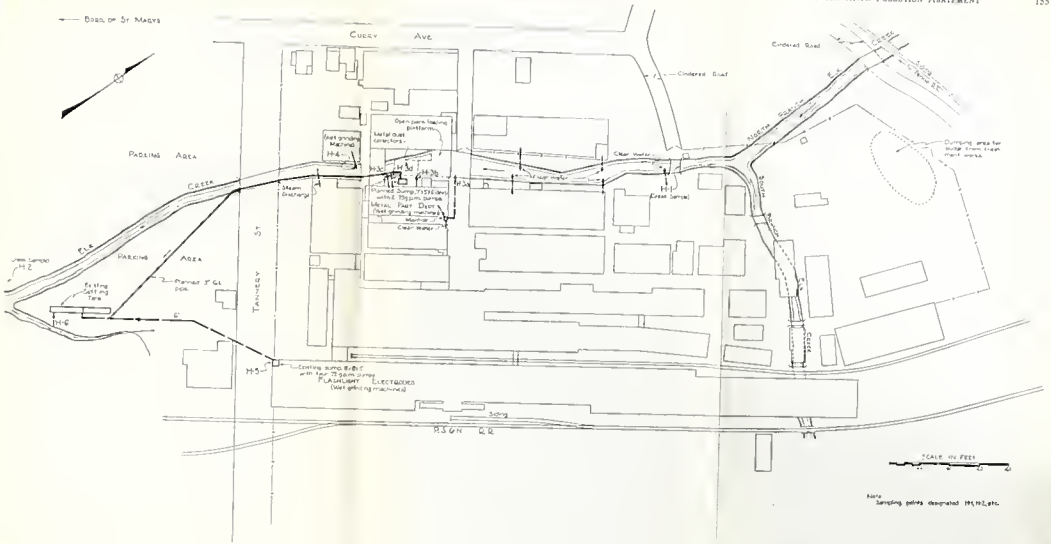

FIGURE 30. STACKPOLE CARBON COMPANY EXISTING AND PLANNED WASTE DISPOSAL WORKS.

leading to the Link-Belt tank as shown in Fig. 30. It is proposed to use in the new sump two of the four 75-gpm pumps from the existing sump.

When this planned improvement is completed, it is expected that the effluent from all wet grinding machines will be excluded from Elk Creek and will be passed through the treatment works. If pumps at both sumps are operating simultaneously, the overflow rate at the treatment works will be 642 gpd per sq ft and the detention period will be 1.68 hours. With both pumps operating, the combined flow will still be somewhat less than the designed flow (167 gpm), and except for the intermittent surges of influent to the treatment works, the design appears to be adequate. For improved efficiency of settling, it is recommended that the pumps be throttled so as to operate continuously during the working day and avoid surges caused by intermittent operation.

A survey of the quantities and strengths of the wastes produced at this plant and the efficiency of the existing treatment works was made on November 5, 1948. A summary of this survey is shown by Table 22. In view of the nature of the wastes and the low BOD results previously obtained by our engineers at the Speer Carbon Company, BOD determinations of the wastes at this plant were omitted. BOD results were obtained, however, for stream samples taken above and below the plant. It is to be noted from Table 22 that the suspended-solids content of the grinder waters is very high but that the other constituents of the wastes are not abnormal.

Samples of the creek water were obtained at 4:15 PM on November 5, 1948, the analyses of which are shown below:

Analysis	*Sample No.* H-1 (*upstream*)	H-2 (*downstream*)
Temperature, °C	18	16.5
pH	10.18	8.63
5-day BOD, 20°C, ppm	70.3	57.6
Dissolved oxygen, ppm	2.71	3.38
Methyl-orange alkalinity, ppm	160	107
Total solids, ppm	1,244	1,028
Volatile total solids, ppm	306	194
Fixed total solids, ppm	938	834
Suspended solids, ppm	184	192
Volatile suspended solids, ppm	92	78
Fixed suspended solids, ppm	92	114
Dissolved solids, ppm	1,060	836
Volatile dissolved solids, ppm	214	116
Fixed dissolved solids, ppm	846	720

These analyses show that, with the exception of a slight increase in the fixed suspended solids, the quality of the stream was actually improved as it flowed past the Stackpole Carbon Company. The high BOD content in

these analyses is attributable to pollution at the tannery of the Armour Leather Company just upstream.

The treatment works removed 96.8% of the suspended solids from the influent to the plant. Considering the entire wastes produced at the Stackpole Carbon Company, the treatment works removed approximately 74.4% of the total suspended solids. The effluent from the treatment works at the Stackpole Carbon Company contained considerably more fine carbon than did the effluent at the Speer Carbon Company as is borne out by a comparison of the suspended-solids contents of the effluents of the two plants. We attribute much of this relatively poor performance of the treatment works at Stackpole to the surges of wastes from the intermittent pump operation. It is probable also that the slurry blanket of the Hardinge clarifier at the Speer Carbon Company improves the quality of that effluent.

Another serious source of pollution of Elk Creek by the Stackpole Carbon Company originates at the open loading platform over the creek shown on Fig. 30. At this point, trucks are loaded with carbon products and certain dry wastes, from which there is much dust and spillage. It is understood that the Company plans to enclose this platform and make it dust-proof. If this plan is not carried out, the truck-loading operations should be moved to another location away from the creek.

In checking the drains along Elk Creek, our engineers discovered that one of the pipes originated at the wash sink in a passageway spanning the creek. Although sanitary sewage and wash water are supposed to be connected to the borough's sewers, this drain and possibly others discharge directly into Elk Creek. It is recommended that this drain be diverted into the sanitary sewers and that a thorough check be made by the Company of all other drains from sanitary fixtures to make certain that none of them discharge into the creek.

The effect of the present effluent from the settling basin upon Elk Creek could not be determined at the time of our survey because the stream was highly polluted by upstream discharges of carbon and tannery wastes. The effluent was quite black and turbid from the residual fine carbon and it is possible that its discharge into a clear stream would cause noticeable discoloration. If this is found to be the case after other pollution at St. Marys has been abated, better removal of carbon granules may be obtained by coagulating chemicals and filtration of the settling tank effluent. We recommend, however, that no action be taken in this respect until upstream pollution has been abated, until the pumps have been throttled to operate continuously and until the discoloring effect of the effluent upon a clear stream can be ascertained.

Recommendations

We recommend that the Stackpole Carbon Company proceed forthwith to construct the planned works to convey all grinder wastes to the existing settling tank and to render the open loading platform dust-proof or to remove it to another location. We further recommend that the pumps in the collecting sumps be throttled so as to discharge continuously and uniformly. When these improvements are completed and when other upstream pollution in Elk Creek has been abated, the effect of the settled effluent upon Elk Creek should be ascertained and further treatment installed, if needed.

TABLE 22. STACKPOLE CARBON COMPANY, ST. MARYS, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED ON NOVEMBER 5, 1948

Sampling Point	Sample No.	Continuous Time of Discharge			Average Rate of Discharge		Total Daily Discharge mg	Temp. °C	Total Solids			Suspended Solids			Dissolved Solids				Alkalinity to pH 4.30 as $CaCO_3$	
		From	To	Total Minutes	gpm	mgd			ppm	lbs/day	% Volatile	ppm	lbs/day	% Volatile	ppm	lbs/day	% Volatile	pH	ppm	lbs/day
Main Sump Grinder Wash. .	H-5	7:30 AM	3:30 PM	200*	31.3	0.0450	0.0150	13.0				1,372	521	29.7				6.42	42.2	5.3
Ink Belt Effluent. . .	H-6	7:30 AM	3:30 PM	200*	30.8	0.0443	0.0148	13.0	525	71	27.1	134	17	83.6	441	54	10.0	6.66	38.0	4.7
Reduction by Treatment							0.0002						504							0.6
% Reduction. . .													96.8%							11.3%
Grinder Wash to Elk Creek. . .	H-3	7:30 AM	3:30 PM	480	15.63	0.0225	0.0075	14.5	2,830	177	60.0	2,484	155	47.0	346	22		7.87	85.9	5.4
Miscellaneous Drain on North Bank. .	H-4	7:30 AM	3:30 PM	480	15.10	0.0218	0.0073	20.0	392	24	31.7	40	2		362	22		6.87	62.9	3.8
Total Wastes Produced . .	H-3, 4 & 5						0.0298						678							14.5
Total Discharge to Elk Creek. . .	H-3, 4 & 6						0.0295			272			174			99				13.9
Total Reduction .							0.0002						504							0.6
% Reduction . . .													74.4%							4.1%

*Intermittent operation—pumps on 5 minutes and off 5 minutes approximately

STRAUB BREWERY

Description

Located a short distance from the south bank of Elk Creek, near the intersection of Brussels Street (Route U. S. 120) and Sorg Street in St. Marys, the Straub Brewery employs about 30 persons and operates one shift a day, from 7:00 AM to 3:00 PM, for five days a week. The brewery uses 12 mg of municipal water and 0.3 mg of well water per year to produce 1.1 mg of beer per year; hence the total liquid industrial and sanitary wastes amount to 11.2 mg per year, or about 43,000 gallons per working day. Sanitary sewage is discharged to the borough's sanitary sewers, but the industrial wastes flow to a storm drain which leads to Elk Creek (see Fig. 31).

The bottle washing and pasteurizing processes constitute the principal sources of wastes at the brewery. The bottles are cleaned by three successive soap and alkali washes, followed by a cold-water rinse and four sprays. The bottles are then filled, pasteurized, corked and inspected on a conveyor.

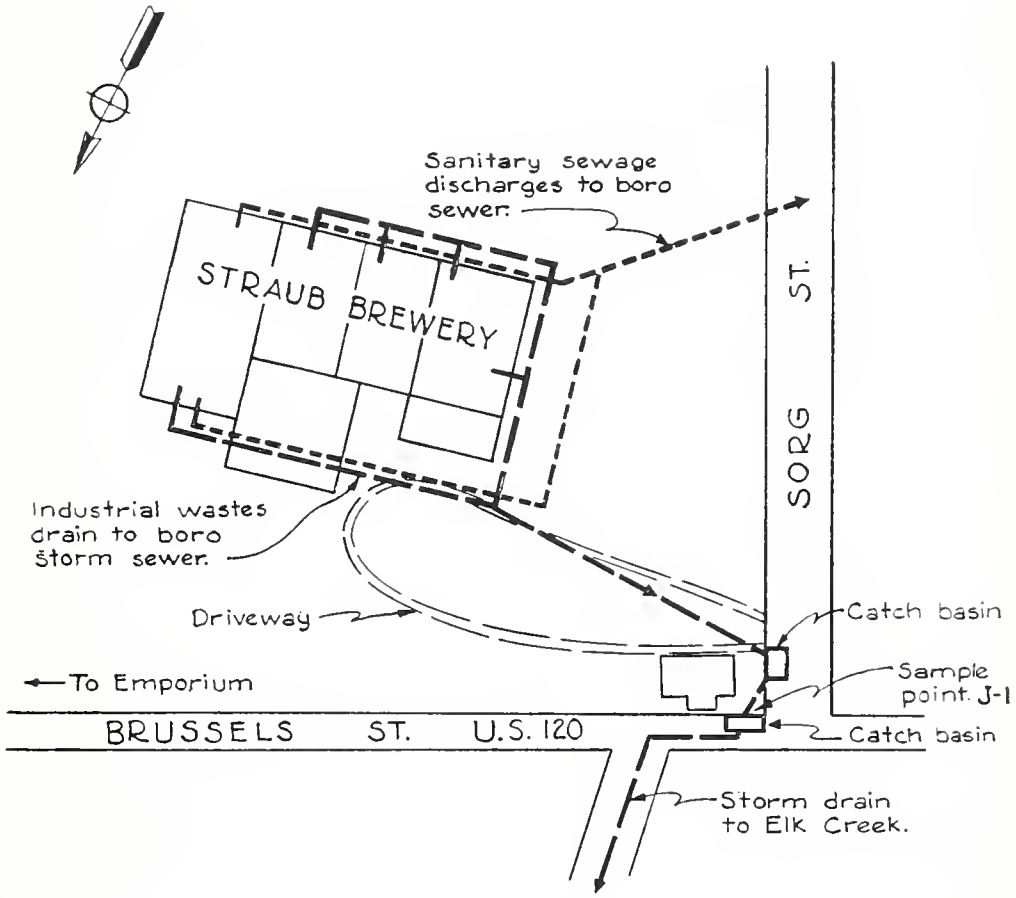

FIGURE 31.

STRAUB BREWERY AT ST. MARYS, PA. SKETCH OF DRAINAGE SYSTEMS

(Not to Scale—March, 1949)

The four brew vats are hosed down about once every four or five days, following the removal of reclaimable yeast. About 10 lbs of yeast are wasted from the cleaning of each vat. It is understood that the mash or beer slop is dewatered and sold to farmers, the liquid effluent being discharged with the plant wastes.

The combined industrial wastes from this plant were gaged at 15-minute intervals on November 18, 1948, and a composite sample was analyzed. As shown on Table 23 the total daily discharge on the day of gaging was found to be 40,300 gallons, which corresponds quite closely, after allowance has been made for the sanitary wastes, to the estimate based on water consumption as explained above. The peak rate of discharge was about 250% of the average rate. Of the analyses shown on Table 23 it is significant to note that the pH of the combined wastes is quite high (10.3) although the alkalinity is not excessive. The temperatures of the wastes varied between 13° and 28°C, depending upon stages of the bottle-cleaning operations. The wastes had a 5-day BOD of 442 ppm, comparable to that of strong domestic sewage. The total BOD load discharged by the brewery is approximately 10% of the BOD load from the population of St. Marys.

At the time of our surveys, there was some question as to the responsibility for treating or otherwise handling the industrial wastes from the Straub Brewery. It is the general policy of the Sanitary Water Board that industrial wastes discharged to a community's sewers become the responsibility of that community. However, the report submitted by Havens & Emerson for treatment of the sewage of the borough of St. Marys specifically excludes brewery wastes from the sanitary system. When our survey was being made, detailed plans for the St. Marys sewage treatment works were being considered for approval by the Sanitary Water Board. If brewery wastes are excluded from the borough's sanitary sewers and if the responsibility for the treatment of such wastes still rests with the borough, the borough would then have the choice of excluding the brewery wastes from all municipal sewers or of constructing a separate treatment works for the brewery wastes alone. Neither of these alternates would be attractive or reasonable, and we recommend therefore that the brewery wastes (exclusive of beer slops or mash) be discharged into the borough's sanitary sewers and treated with the borough's sewage as explained hereinafter. The effect of this waste upon the strength and pH of the combined wastes is discussed in detail for the comprehensive plan for St. Marys.

The combined treatment of brewery wastes with those of the borough and tannery will require enlargement of the proposed St. Marys treatment plant, as described hereinafter, but it will avoid the necessity of constructing a separate treatment works for the brewery.

Recommendation

We recommend that the Straub Brewery pay an equitable share of the construction cost of the combined treatment plant and we estimate this share to be $23,000, or if bonded by the borough for 20 years at 2.5% interest, about $1,450 per year. In addition, the brewery should pay an equitable share of the annual operating and maintenance costs of the combined plant, which we estimate to be $770 per year.

TABLE 23. STRAUB BREWERY, ST. MARYS, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY NOVEMBER 18, 1948

Discharge Data

Total daily discharge	40,300 gallons
Period of discharge	9 hours
Average rate of discharge	74.7 gpm
Peak rate of discharge	190 "

Analyses

pH	10.3
Temperature	13° to 28°C

	ppm	*lbs per day*	*% Volatile*
BOD (5-day, 20°C)	442	148	—
Total solids	1,065	358	79
Suspended solids	312	105	86
Dissolved solids	753	253	76
Alkalinity to pH 8.2 as $CaCO_3$	76	26	—
Alkalinity to pH 4.3 as $CaCO_3$	178	60	—

ARMOUR LEATHER COMPANY

Description

The tannery of the Armour Leather Company in St. Marys is located just upstream from the Stackpole Carbon Company on the south branch of Elk Creek, as shown in Fig. 1. The Company produces sole leather by the vegetable tanning process, using approximately 24,000 lbs of raw hides per day. At the time of our survey, the plant was operating 5 days per week, with liquid wastes being produced from about 6:30 AM to about 4:30 PM. Process water is obtained from two sources, about 1 mg per month from a well on the premises equipped with a water softener and about 1 mg per month from the borough's system. The total average water consumption is approximately 90,000 gpd on the basis of 22 work days per month. Sanitary sewage from the mill and from mill-owned houses along Tannery Street discharges into the mill drainage system and is treated with the industrial wastes. Liquid wastes are produced from the raw hide soak, the lime and sulfide soak, rinse processes, drippings from the fleshings, dehairing, beaming and flushing operations, bate baths, spent tan liquors and the scrub house. All of these wastes drain through a network of 27 ditches and pipes to a 12 ft x 12 ft concrete sump as shown in Fig. 32 from which they are pumped intermittently by a 160-gpm pump to the treatment works. It is important to note on Fig. 32 that the wastes flow through open ditches for part of their course, and hence are diluted by storm-water run-off during periods of precipitation. When the total flow in the ditches exceeds the capacity of the pumps, the excess wastes overflow to Elk Creek.

Existing Methods of Waste Disposal

In addition to the network of drains, the sump and the pump described above, the treatment facilities at the Armour Leather Company comprise a holding or equalizing tank, a primary settling device, sludge drying beds, a long effluent ditch and a spent-tan-liquor lagoon. The layout of these facili-

ties with relation to the plant structures is shown in Fig. 32. The holding tank is 43.5 ft long x 25 ft wide x 13 ft effective depth with a capacity of 106,000 gallons. It is equipped with four sets of paddles driven through vertical shafts by electric motors. While these paddles serve to minimize sedimentation within the holding tank, they were probably installed for the purpose of aiding flocculation. From the holding tank, the wastes are lifted by a diaphragm pump for about 22 hours each day to an Infilco tray clarifier. This unit consists of four trays, each 26 ft long x 10 ft wide, spaced 2.5 ft apart vertically. Scrapers operating at the rate of ½ ft per minute remove the sludge from the trays into a sump from which it is pumped by a diaphragm pump to the elevated sludge trough leading to the sludge drying beds as shown in Fig. 32. The effluent from the tray clarifier discharges through a 4-in. pipe into an effluent ditch which leads to the south branch of Elk Creek.

At the time of our survey, the effluent from the tray clarifier was gaged at 42 gpm and the sludge trough was carrying 18 gpm, making the diaphragm pump capacity and the total flow through the tray clarifier equal to 60 gpm. On that basis, the overflow rate for a total surface area of 1,040 sq ft in the tray clarifier was 83 gpd per sq ft and the theoretical detention period was 5.4 hours.

Sludge is conveyed by a distributing system of elevated troughs to drying beds with a total area of about one acre. For a daily sludge production of 23,100 gallons and a suspended solids removal of 2,530 lbs per day, as determined by our gagings and analyses, the moisture content in the raw sludge was computed to be 98.7%. The total depth of liquor drawn onto the beds is estimated at 18.7 ft per year and the total depth of dried sludge removed is reported at about 16 inches per year. The moisture content of the sludge cake is then calculated to be about 83%.

Since in the operation of municipal sewage treatment plants it is seldom possible to draw more than a total of 5 ft of sludge per year onto well-drained beds, it is quite unlikely that the sludge beds at this tannery are taking over 18 ft per year by evaporation and sub-surface drainage. Each bed at the tannery is equipped with an arrangement for decanting the supernatant to the ditch or stream, and decantation is apparently being done after the sludge in any bed has had a supplementary period of settling. We estimate that about 12 to 15 ft per year, or about 15,000 to 18,500 gpd, of supernatant is so decanted. This represents a further pollution of the stream.

Spent tan liquors are drained into a sump from which they are pumped either to a lagoon as shown on Fig. 32 or into a tank truck to be hauled by the Keystone Tanning and Glue Company to its evaporating plant in Ridgway. Whenever the market for tan-liquor extract is unfavorable or whenever evaporating capacity is not available, the Keystone Tanning and Glue Company does not send a tank truck for the spent tan liquors at the Armour Leather Company and at such times the tan liquors are pumped into the lagoon. If the lagoon becomes filled, the contents are decanted directly into the south branch of Elk Creek, causing organic pollution and rendering the water in that stream black from the reaction of the iron and pyrogallates. Inasmuch as the average daily production of tan liquors ranges from 8,000 gpd to about 10,000 gpd and the spent-tan-liquor lagoon has a

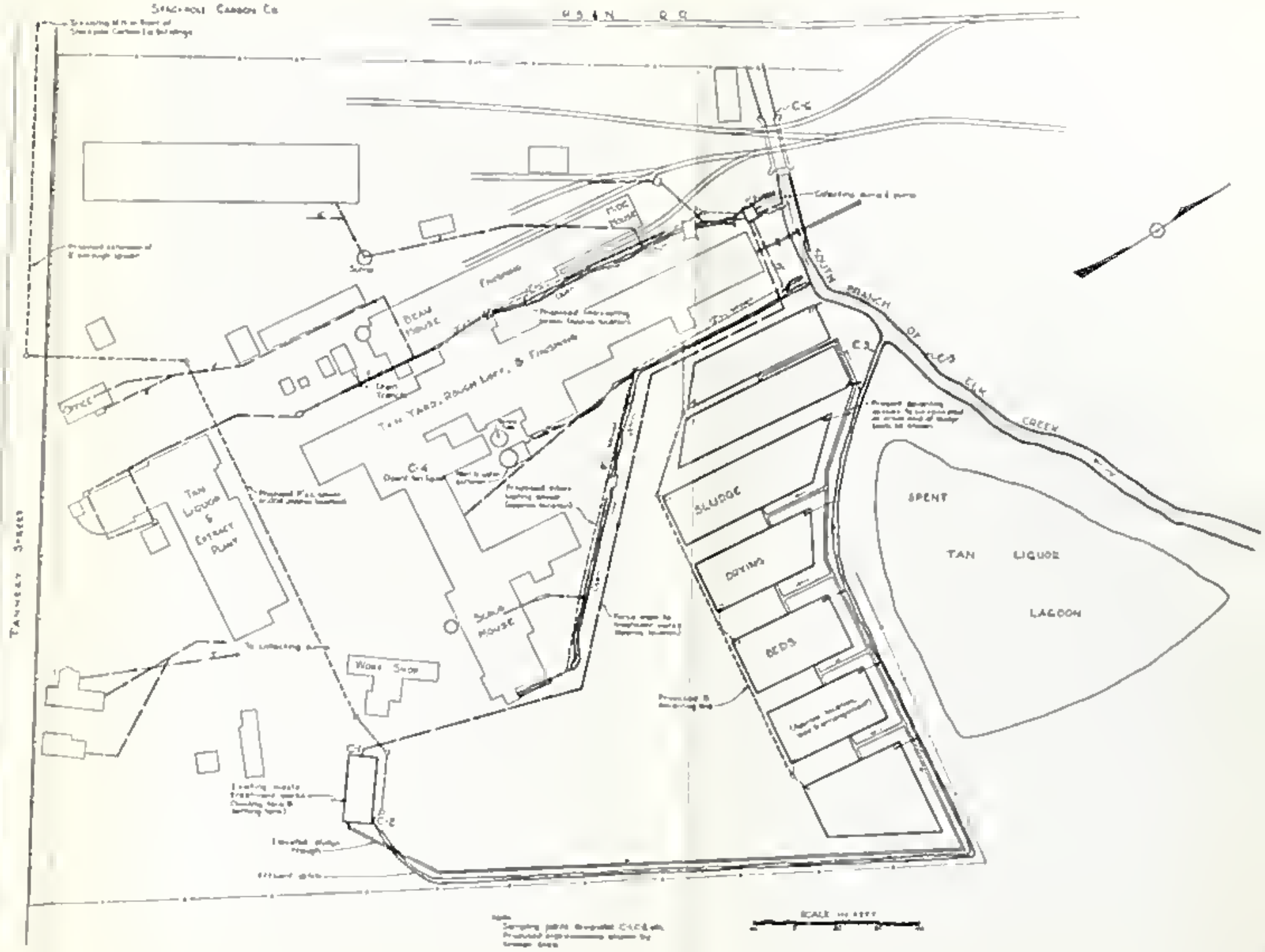

FIGURE 32. ARMOUR LEATHER COMPANY EXISTING WASTE DISPOSAL WORKS AND PROPOSED IMPROVEMENTS.

TABLE 24. ARMOUR LEATHER COMPANY TANNERY, ST. MARYS, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED OCTOBER 20, 1948

Sampling Point	Sample No.	Continuous Time of Discharge: From	To	Total Minutes	Average Rate of Discharge: gpm	mgd	Total Daily Discharge mg	Temp °C	5 Day, 20° C BOD: ppm	lbs/day	SOLIDS: Total Solids: ppm	lbs/day	% Volatile	Suspended Solids: ppm	lbs/day	% Volatile	Dissolved Solids: ppm	lbs/day	% Volatile	pH	Alkalinity to pH 4.30 as $CaCO_3$: ppm	lbs/day	Total Sulfides as S=: ppm	lbs/day
Treatment Plant Influent at Holding Tank	C-1	6:30 AM	4:30 PM	550(1)	142	0.2090	0.0798	12 to 23	1,777	1,180	12,281	8,163	28.5	4,356	2,895	56.2	7,927	5,270	12.9	11.30	2,150	1,430	14.2	9.4
Effluent from Tray Clarifiers (Total Wastes to Elk Creek)	C-7	6:30 AM	5:00 AM	1350	42	0.0605	0.0567	15	776	366	6,908	3,265	19.1	772	365	71.0	6,136	2,900	12.6	11.42	1,100	520	7.0	3.2
Reduction by Treatment Plant (Without credit for equalization). % Reduction							0.0711			811 69.0%					2,330 87.3%			2,270 43.0%				910 61.0%			6.1 64.9%
Reduction by Treatment Plant (With credit for equalization) % Reduction										1,017 86.1%					2,733 91.3%			2,960 72.2%				1,190 53.8%			7.9 84.1%
Effluent from Dutch to Elk Creek*	C-3	0:30 AM	5:00 AM	1350	47	0.0605	0.0567	15	781	369	7,034	3,325	20.7	756	357	20.6	6,278	2,965	20.7	11.40	1,090	515	3.4	1.6
Spent Tan Liquor	C-1						0.0079	25	42,330	2,800	61,390	4,040	89.4	27,475	1,810	96.4	33,920	2,230	83.6	4.12	250	16		
Total Wastes Produced at Tannery (C-1 + C-4)							0.0877		5,450	3,980	16,220	12,205		6,450	4,705		10,270	7,500			1,930	1,416	12.9	9.1
Total Reduction (Without credit for equalization). % Reduction										2,614 90.8%		8,910 72.2%			4,340 92.2%			1,600 81.4%				926 64.0%			6.1 64.9%
Total Reduction (With credit for equalization). % Reduction										2,817 93.9%		10,725 85.1%			4,563 96.2%			6,210 82.8%				1,212 81.0%			7.9 84.1%

*Flow quantities estimated equal to effluent from tray clarifiers by proportioning

capacity of about 1.5 mg, we estimate that there is sufficient capacity in the lagoon for over 6 months' production of spent tan liquors.

Effectiveness of Waste Treatment

A survey was made of the quantity and strengths of industrial wastes produced at the Armour Leather Company tannery on October 20, 1948, at a time when operation was approximately normal. The results of this survey are presented in Table 24 and the points at which samples were taken are shown by numbers on Fig. 32.

On the date of this survey, the total daily discharge from the main collecting sump to the holding tank was 79,800 gallons in about 10 hours. This quantity checks fairly closely with the 90,000 gpd average water consumption. The wastes were pumped for 22½ hours from the holding tank through the tray clarifier at an average rate of 60 gpm, of which 42 gpm was discharged to the effluent ditch and 18 gpm to the sludge drying beds. Spent-tan-liquor production was reported at 7,900 gpd. The data presented in Table 24 show that the treatment plant effected a removal of 69.0% of BOD, 60.0% of total solids, 87.3% of suspended solids, 63.6% of alkalinity and 64.9% of total sulfides, all on a 10-hour basis. If credit is allowed for the equalization accomplished by the holding tank, the efficiencies are increased to 86.2% for BOD, 82.3% for total solids, 94.3% for suspended solids, 83.8% for alkalinity and 84.1% for total sulfides. Considering that the spent tan liquors were being excluded from the stream by being hauled to Ridgway, the total reduction by all pollution-abatement measures is computed to be 95.9% for BOD and 96.5% for suspended solids.

While these percentage removals may appear impressive, they are nevertheless not sufficient inasmuch as the small drainage area of the south branch of Elk Creek causes its assimilative capacity to be very low. We have computed this assimilative capacity at drought flow to be no higher than 280 lbs of 5-day BOD per day as contrasted with the 366 lbs per day being discharged to the stream.

On the date of the survey at the tannery, we also sampled the south branch of Elk Creek just upstream from the point where the effluent ditch from the treatment plant enters the creek and also at the railroad bridge downstream from the tannery but upstream from the Stackpole Carbon Company. The results of this survey are as follows:

Analysis	*Sample No.* *C-5* *(Upstream)*	*C-6* *(Downstream)*
Temperature	8°C	10°C
pH	3.62	9.18
Methyl-orange alkalinity	14 ppm	95 ppm
Dissolved oxygen	9.01 "	4.98 "
5-day BOD	1.52 "	70.2 "
Total solids	556 "	1272 "
Total fixed solids	424 "	1006 "
Total volatile solids	132 "	266 "
Suspended solids	50 "	120 "

The stream flow at the time of sampling was approximately 0.4 cfs per sq mi and yet the dissolved-oxygen content immediately below the point of pollution had dropped below 5 ppm. During drier periods, it is expected that dissolved oxygen will be almost exhausted in the south branch of the Elk Creek as a result of the BOD in the tannery wastes.

The last column of Table 24 shows the total sulfides in the influent and effluent at the treatment works and also at the effluent end of the ditch discharging into Elk Creek. Approximately 73 lbs of Na_2S are used per day in the lime soaks, which is equivalent to about 30 lbs per day of sulfides. Of this amount 9.4 lbs per day appeared at the treatment plant influent and only 1.6 lbs per day at the effluent end of the ditch, indicating that, of the total amount of sulfide used at the tannery, only about 5% reaches the stream. At a pH of approximately 9.2 in the stream, this sulfide content did not result in the production of H_2S odors. During the course of our surveys of Elk Creek in and near St. Marys, there was no evidence of H_2S odor in the stream. If oxygen is exhausted from the stream, however, or if the pH is lower, it is probable that these residual sulfides would result in the evolution of H_2S gas and odors.

As might be expected, the odor and appearance of the effluent from the treatment works are decidedly unfavorable, with a typical tannery odor and a reddish brown turbid appearance. Unlike the tanneries at Wilcox and Ridgway, this tannery is not favored by adequate stream-flow dilution to adsorb and otherwise mask the unfavorable appearance. Consequently, the south branch of Elk Creek below the tannery was observed to be blackish in appearance and highly turbid. Much of this blackish appearance is due to the reaction between the pyrogallates in the tan liquors which manage to get into the treatment plant and the iron in the acid stream. It is to be noted that the pH of the south branch upstream from the point of tannery discharge was only 3.62 but rose to 9.18 after the tannery wastes were added.

A comparison of the wastes at the Armour Leather Company as shown in Table 24 with those at the Wilcox and Ridgway tanneries as shown in Table 17 and Table 25 reveals that the treatment plant influent at the Armour tannery is approximately twice as strong with respect to BOD as that at the other tanneries. Also, the BOD of the spent tan liquors at the Armour tannery is much higher than that of the tan liquors at the other plants. Moreover, the spent tan liquors at Armour tannery have a very high suspended-solids content as compared with the spent tan liquors at Wilcox and Ridgway. The spent tan liquors at the Armour tannery contain noticeable quantities of fleshings, hair and other impurities which normally are removed in the beam house. Furthermore it was noted that the treatment-plant influent and effluent at the Armour tannery showed evidence that much tan liquor was reaching the treatment works, probably from the scrub house. It is probable, therefore, that the strength of the treatment plant influent could be reduced materially by modifications in the tannery processes so as to minimize the amount of tan liquor which mixes with the other wastes. Similar care should also be exercised to prevent certain beam house wastes from mixing with the spent tan liquors. These are matters of good housekeeping at a tannery and their proper attention should materially reduce the strength of all wastes.

The tannery uses 2,240 lbs per day of lime. If we estimate that 46% of this lime appears in the effluent, as at the Wilcox tannery, we can expect the calcium discharged with the effluent to be approximately 1,830 lbs per day, expressed as $CaCO_3$. This quantity of calcium will increase the hardness in the south branch of Elk Creek by 17 ppm at the 50% flow and by 170 ppm at the drought flow. It can be seen therefore that even without the pollution caused by BOD, color, and appearance, the calcium content of the wastes at the Armour Leather Company is sufficiently great to cause pollution with respect to hardness. Fortunately, however, water from Elk Creek is not used for any process purposes, to the best of our knowledge, until after dilution has been adequate to render this high calcium concentration ineffectual.

Comments on Present Waste Disposal

As a summary of our survey of the Armour Leather Company tannery, the following defects in the waste disposal system are enumerated:

(1) Sanitary sewage is mixed with the industrial wastes and discharged after primary sedimentation only. While it is true that the high pH value of the wastes exercises a bactericidal effect in about four hours, the actual detention period in the holding tank and tray clarifier (about 6 hours minimum) does not offer a sufficient margin of safety because of short-circuiting.

(2) Open ditches on the property allow storm water to mingle with industrial wastes and sanitary sewage and to cause the mixture to overflow directly into Elk Creek. These overflowing wastes contain settleable solids which add to the formation of sludge banks in lower reaches. Just as separate sanitary sewers and storm drains are desirable for municipalities, so should storm water be excluded from the industrial wastes drainage system at this plant.

(3) Supernatant is decanted from the sludge lagoons into the ditch or into Elk Creek and thus adds to the pollution load.

(4) The disposal of tan liquors at this plant is satisfactory only so long as they are hauled to Ridgway for evaporation. Disposal into the spent-tan-liquor lagoon is satisfactory for short periods of time, but the practice of decanting to the stream during periods of high flow cannot be condoned because it causes discoloration and increases the organic loading beyond the assimilative capacity of the stream.

(5) Dilution in the south branch of Elk Creek during low periods of flow is not adequate to assimilate the present routine discharges from the tannery with respect to BOD, color, appearance, and hardness. The low assimilative power of the stream is particularly critical at this point inasmuch as the tannery lies upstream from the borough of St. Marys and the polluted stream flows through the center of the built-up district of the borough. After the odor-masking effect of the fine carbon granules at the Stackpole Carbon Company is minimized by the proposed improvements to treatment at the carbon plant, we anticipate that the condition of Elk Creek as it passes through St. Marys will be worse than at present unless remedial measures are also taken at the tannery.

Recommendations

In order to abate the organic pollution in the south branch of Elk Creek, we recommend that the tannery discharge the effluent from its settling tank and its sanitary sewage into the borough's sanitary sewers, to be treated with the borough's sewage as described later in this chapter. By this means, the organic and bacterial pollution load will be diverted from the south branch to the treatment plant which will discharge into Elk Creek downstream from the borough. At that point the drainage area and stream flow are about six times as great as at the tannery. We also recommend that the Armour Leather Company endeavor to reduce the strength of its wastes by proper housekeeping procedures within the tannery, so as to minimize its organic load upon the borough's treatment plant.

The nearest sanitary sewer of the borough terminates in front of the Stackpole Carbon Company on Tannery Street. To make a connection to this sewer we recommend that the borough extend its 8-in. sewer for about 400 ft along Tannery Street at an estimated cost of $2,900 and that the Armour Leather Company construct about 630 ft of sewer from the outlet of the present treatment works to the extended borough sewer, as shown on Fig. 32, at an estimated cost of about $4,600. These estimates include an allowance for contingencies and engineering.

The combined treatment of tannery wastes with the wastes of the borough and brewery will require enlargement of the proposed St. Marys treatment plant as described hereinafter, but it will avoid the construction of a secondary treatment plant for the tannery. We recommend, therefore, that the Armour Leather Company pay an equitable share of the construction cost of the combined treatment plant based on loadings of flow, BOD, solids and excessive phenolphthalein alkalinity. We estimate this share to be $59,000 or if bonded by the borough for 20 years at 2.5% interest, about $3,730 per year. In addition, the tannery should pay an equitable share of the annual operating and maintenance costs of the combined plant. We estimate this share to be about $1,970 per year.

In the event that the effluent from the present treatment works is not taken into the borough's sewers, as recommended, it should be subjected to secondary treatment before being discharged to the south branch of Elk Creek. We have made a preliminary design for secondary treatment facilities comprising a carbonation chamber for pH neutralization, duplicate high-rate trickling filters, secondary settling tanks, recirculation of the final effluent at an average ratio of 3 to 1, and additional sludge drying beds, at a total estimated cost of $76,000, including contingencies and engineering. This alternate to combined treatment with the borough's sewage is not satisfactory because the plant will cost the Armour Leather Company more than its equitable share of the combined plant and because the discharge of treated effluent to the stream above St. Marys will result in high color and hardness. We recommend, therefore, that this alternate method of handling the effluent from the settling tanks be considered only in the event that no agreement with the borough can be consummated.

To prevent overflows of mixed wastes and surface run-off during rainstorms, we recommend that the industrial wastes now discharging into the open ditches be intercepted by new closed drains and conveyed to the collecting sump. Roof drainage and surface run-off should continue to be dis-

charged to the open ditches. The construction cost of the proposed 8-in. and 12-in. vitrified-clay sewers and the necessary manholes is estimated at $6,000, including contingencies and engineering.

We further recommend that the supernatant from the sludge drying beds be decanted into a new 8-in. sewer south of the drying beds and conveyed to the collecting sump, as shown on Fig. 32, and that the present method of decanting to the creek be discontinued. The cost of the new 8-in. sewer, manholes and connections to the sludge beds is estimated at $2,800, including contingencies and engineering.

With respect to the disposal of spent tan liquors, we recommend that the present arrangement with the Keystone Tanning and Glue Company be continued, that every effort be made to facilitate and encourage this arrangement, and that disposal to the lagoon be practiced only when absolutely necessary. In no event should the spent tan liquors in the lagoon be decanted to the south branch of Elk Creek, nor should they ever be discharged along with the effluent from the settling tank to the borough's sewers, because they will discolor the waters of the creek and add an organic load which during periods of high flow will be carried into Piney Reservoir.

In the event that the Keystone Tanning and Glue Company is unable or unwilling to take the spent tan liquors most of the time, so that the capacity of the lagoon will not be exceeded by frequent disposal thereto, we recommend that the Armour Leather Company construct its own evaporating plant. The cost of construction of such a plant, including boiler, quadruple-effect evaporators, a drum drier, the necessary pumping and piping arrangements and a new building is estimated at approximately $150,000. The annual cost of operation and maintenance may be offset by income from the sale of the product.

ST. MARYS MEAT PACKING COMPANY

Description

This plant is located on a high plateau between Elk Creek and Powers Run, about three miles from St. Marys on the road to Johnsonburg, as shown on Fig. 1. It is a small establishment for the slaughtering and processing of local meat. Liquid wastes are produced primarily from floor washings, and contain bits of flesh, hide, dung, grease and considerable blood. These wastes amount to about 2,000 gpd and drain into a tank in the adjacent yard, from which they are hauled by tank truck to an isolated spot and dumped. Grease is partially recovered in traps and reclaimed. It is understood that this method of disposal has been approved by engineers of the Pennsylvania Department of Health. Inasmuch as no evidence was found that these wastes reach the streams, no further consideration was given in our survey to this plant.

BOROUGH OF ST. MARYS

Discussion

According to the 1940 census, the population of the borough of St. Marys was 7,653 and it has been estimated that the 1948 population within the borough limits is about 8,100 persons. In addition, there are about 2,000 persons living in contiguous areas which might be sewered into the borough's system. In 1907, a comprehensive plan for sanitary sewers was prepared for the borough by Alexander Potter, Consulting Engineer. The

system was designed for sanitary sewage only and to discharge into Elk Creek near the mouth of Iron Run, with the understanding that a sewage treatment plant would be built at some future date. Storm-water run-off and roof drainage was rigorously excluded from this system. Potter's plan has been carefully followed as the borough grew and the sewers were extended, which is a tribute to the wisdom of the borough officials and the borough engineer. At the present time, it is understood that the sewers receive in addition to sanitary wastes certain process wastes from a carbonating plant and several dairies, but no industrial wastes from the carbon plants, the tannery or the brewery.

The Sanitary Water Board directed the borough on February 21, 1945 to submit a report and detailed plans for complete sewage treatment works on or before September 21, 1945. It is understood that the borough failed to comply with this directive and consequently was referred to the Department of Justice in November, 1946. An extension of time was granted because a new highway was being constructed through the proposed treatment plant site, which necessitated the selection of another site. Plans have finally been submitted and are now in the process of being reviewed by engineers of the Department of Health.

Reports on the problem of sewerage and sewage treatment at St. Marys were prepared by Gascoigne & Associates in 1938 and by their successors, Havens & Emerson in 1948. These engineers estimated that the sewered population of the borough of St. Marys and contiguous areas would be approximately 10,000 persons by 1965, that the average sewage flow would be 1.0 mgd and that the per capita contribution of suspended solids and BOD would be 0.2 and 0.22 lbs per day respectively. They recommended the construction of a chamber for the removal of screenings and grit on the south bank of Elk Creek near the point of present discharge, followed by a pressure pipeline under the creek to a sewer leading to a treatment plant on the north bank. The proposed treatment works for which plans have been submitted comprise a Venturi tube for flow measurement, an Imhoff tank, a dosing siphon, two standard low-rate trickling filters, a final settling tank, effluent chlorination, and open sludge drying beds. It was estimated by the engineers that this plant would cost $394,000, based on mid-1948 construction costs.

The allowable increment of BOD loading in Elk Creek at the point where the sewage treatment plant will discharge is shown by Table 13 to be 300 lbs per day of 5-day BOD. Based on Havens & Emerson's estimated future BOD loading of 2,200 lbs per day, the proposed treatment works would be required to remove 86.4% of the BOD, a removal which should readily be accomplished by the type of plant proposed. We estimate the total present BOD loading of Elk Creek by the tannery and brewery as well as by the borough's sewage to be 2,190 lbs per day of 5-day BOD, as shown in Table 13.

Recommendations

For the best interest of all concerned with stream-pollution abatement in the St. Marys area we recommend that the settled tannery wastes (exclusive of tan liquors) and the brewery wastes be discharged to the borough's sanitary sewers and treated in a combined plant. The addition of the brewery and the tannery wastes will require certain changes, enlargements and addi-

tions to the plant designed by Havens & Emerson. The industrial wastes, for example, have high pH values which led us to suspect that a mixture of these wastes with the sewage would result in a pH too high for biological treatment. To measure this effect, we mixed tannery and brewery wastes with a composited sample of St. Marys' sewage in proportion to present anticipated daytime flows with the following results:

Source of Waste	*pH*	*Phenolphthalein Alkalinity in ppm as $CaCO_3$*
Straub Brewery	10.76	75
Armour Leather Company	11.28	635
St. Marys Sewage	7.20	0
Anticipated Daytime Mixture	9.07	33

During the night, when sewage flows are weak but the tannery discharge is the same as during the daytime, it is anticipated that the pH of the mixture will be even higher. It is probable, therefore, that neutralization of the wastes will be required. We recommend that this be done at the treatment works rather than at the industries, in order to provide better control and to avoid possible putrescent odors in the sewers. We propose that this neutralization of pH be accomplished by means of a carbonation tank in which flue gasses will be diffused through the mixed wastes. The tank may also be used for pre-aeration of the wastes.

To care for the added flow and the increased load of suspended solids and BOD at the treatment works, we estimate that the surface area of the Imhoff tanks and final settling tanks should be increased by about 10%, the sludge compartment of the Imhoff tank and the sludge drying beds by about 17% and the area of the trickling filters by about 25%. The total anticipated BOD loading of the treatment plant, based on Havens & Emerson's loadings for St. Marys' sewage plus 400 lbs per day from the tannery and 150 lbs per day from the brewery, will be 2,750 lbs per day. On that basis a removal of 89% of the BOD will be required for drought flows in Elk Creek. To assure adequate dissolved oxygen in Elk Creek during periods of drought flow, it will be necessary to aerate the final effluent from the treatment plant before it is discharged to the creek. We propose, therefore, that diffused-air aeration be provided following an adequate chlorine contact period.

Cost of Treatment Works

The increase in cost of the complete treatment works to handle the brewery and tannery wastes (not including spent tan liquors), with provisions for pre-carbonation and effective post-aeration, is estimated at $58,000, making the total estimated cost $452,000. If this total cost is shared by the borough, brewery and tannery in proportion to their contributions of flow, BOD, suspended solids, with the full cost of the carbonation facilities being charged against the tannery and brewery, we estimate the equitable division of the construction cost of the combined sewage treatment plant to be as follows:

Borough of St. Marys	$ 370,000
Straub Brewery	$ 23,000
Armour Leather Company	$ 59,000

For the treatment plant for St. Marys' sewage alone we estimate that the cost of maintenance and operation, including such items as power, gas, chemicals and personnel, will be $14,000 per year. For the combined treatment works we estimate the cost of maintenance and operation to be $15,100, to be shared about as follows:

Borough of St. Marys	$ 12,360
Straub Brewery	$ 770
Armour Leather Company	$ 1,970

In addition to the savings in cost which will accrue to the borough if a combined treatment plant is built and the cost thereof equitably shared by the industries, the borough will also benefit from a cleaner stream flowing through the business district than would otherwise be the case. We recommend, therefore, that the officials of the borough cooperate with the industries to achieve maximum pollution abatement at the least over-all cost by means of a combined treatment plant.

CHAPTER VIII.

CLARION RIVER AT RIDGWAY

The Clarion River at Ridgway receives liquid wastes from the Eagle Valley Tannery of the Keystone Tanning and Glue Company and from the borough of Ridgway, and Elk Creek receives wastes from the Sinclair and Valentine Company plant.

EAGLE VALLEY TANNERY, KEYSTONE TANNING AND GLUE COMPANY

Description

Eagle Valley Tannery is located in Ridgway on the east bank of the Clarion River just upstream from the mouth of Elk Creek, as shown in Fig. 1. About 300 persons are employed during a 5-day work week and the normal operating hours extend from about 3:30 AM to about 4:00 PM, with most liquid wastes being produced between 6:30 AM and 3:30 PM. Water for industrial processes, the power plant and sanitary uses is obtained from two sources: about 430,000 gpd from the municipal supply and about 75,000 gpd from a well on the premises. Sanitary sewage is discharged to the nearest mill drain and mixes with the industrial wastes. The tannery produces about 35,000 lbs per day of sole leather by the vegetable tanning process and in addition to the regular tannery, this main plant of the Keystone Tanning and Glue Company has a central laboratory for eleven tanneries, an experimental tannery, a cut-sole plant, a spent-tan-liquor evaporating plant and a hide-powder manufacturing plant.

In the main tannery, liquid industrial wastes are produced from the raw-hide soak, lime and sodium-sulfide soaks, hot rinse tanks, drippings from fleshing, dehairing and beaming operations, bate bath, tan vats and the scrub house. The experimental tannery produces similar wastes but in much smaller quantities and in an irregular fashion depending upon the experiments being conducted. The cut-sole plant and the hide-powder division are dry processes, but the spent-tan-liquor evaporating plant discharges mixed condensate and cooling waters as described below.

Existing Treatment Works

A layout of a portion of the tannery property showing the existing waste disposal works is presented in Fig. 33. Beam-house wastes are collected by a series of ditches and pipes, and discharged into a beam-house sump (A-1). The rate of discharge into this sump varies considerably inasmuch as most of the wastes originate from the dumping of vats. From this sump, the beam-house wastes are pumped by duplicate 600-gpm centrifugal pumps into a wooden preliminary settling tank as shown on Fig. 33. With one pump operating, the discharge rate is approximately 580 gpm and with both pumps operating about 830 gpm. The preliminary settling tank removes very coarse solids which are drained into a dump truck and hauled to the sludge drying area to the south of the cut-sole plant. After preliminary

settling, the beam-house wastes discharge into the flocculation chamber where they are joined by the other wastes described below.

Wastes from the scrub house and experimental tannery discharge into a circular sump near the preliminary settling tank (see Fig. 33). This sump also receives the effluent from the sludge centrifuges and the combined wastes are then pumped to the flocculation chamber. This chamber is 16 ft long x 33 ft wide with a water depth of 13 ft. At an average rate of flow of about 580 gpm, it has a detention period of about 1.5 hours. Following flocculation the wastes pass directly to the primary settling tank, which is 70 ft long x 33 ft wide with an average water depth of 13 ft. At the average rate of flow it provides a detention period of about 6.5 hours and an overflow rate of about 360 gpd per sq ft. The effluent from the settling tank discharges into an equalizing basin with an area of approximately 7,060 sq ft, a depth of about 7 ft, and a volume of about 370,000 gallons. By means of two swing-jointed float-supported effluent pipes, the effluent from the equalizing basins is withdrawn more or less uniformly during a 24-hour period, thereby equalizing the discharge of wastes which are produced during an 8-hour operating day. Sludge from the settling tank is pumped to a centrifuge house where it is partially dewatered by three 40-in solid-wall basket centrifuges. Operating at a rate of 15 gpm each, these centrifuges can dewater one day's production of sludge in 16 hours. The dewatered sludge is hauled and dumped on open ground to the south of the cut-sole plant. The effluent from the centrifuges is drained to the main collecting sump. While they serve to thicken the sludge somewhat, the operation of these centrifuges is quite unsatisfactory in that they remove the coarse, heavy solids and return the light flocculent material to the treatment works which results in a build-up of very light sludge in the settling tank.

The miscellaneous drain (A-4) shown on Fig. 33 receives much of the sanitary sewage from the plant, floor washings, some beam-house wastes and surface run-off from yards and roofs during rainstorms. At the time of our survey this drain was discharging directly to the river, but a diversion manhole has been inserted on the line and it is possible to divert this flow into the scrub-house sump. Furthermore, it is possible to divert the flow from the preliminary settling tank and beam-house sump into this miscellaneous drain and we understand that this is done after about 4:00 PM when there is very little beam-house drainage. This miscellaneous drain constitutes a source of untreated wastes and as such, it is the subject of our major recommendation with respect to this plant as described below.

Spent tan liquors from this tannery (about 14,000 gpd) are pumped into a collecting tank and there mixed with spent tan liquors which are hauled from the Wilcox and Clearfield tanneries of the same company and at times from the Armour Leather Company in St. Marys. These liquors are then concentrated by a quadruple-effect evaporator from about 3.5% solids to about 50% solids. The condensate from this evaporator mixes with cooling water and discharges to the Clarion River through drain A-8. The tarry residue is then pumped to drum driers where it is converted into a powder, which is sold for various uses requiring an organic binder. Occasionally this plant receives evaporated tan liquors (50% solids) from a tanner near Noxen, Pennsylvania. The condensate from the drum driers, about 900 gpd, passes through a barometric seal where it is diluted and then discharges to

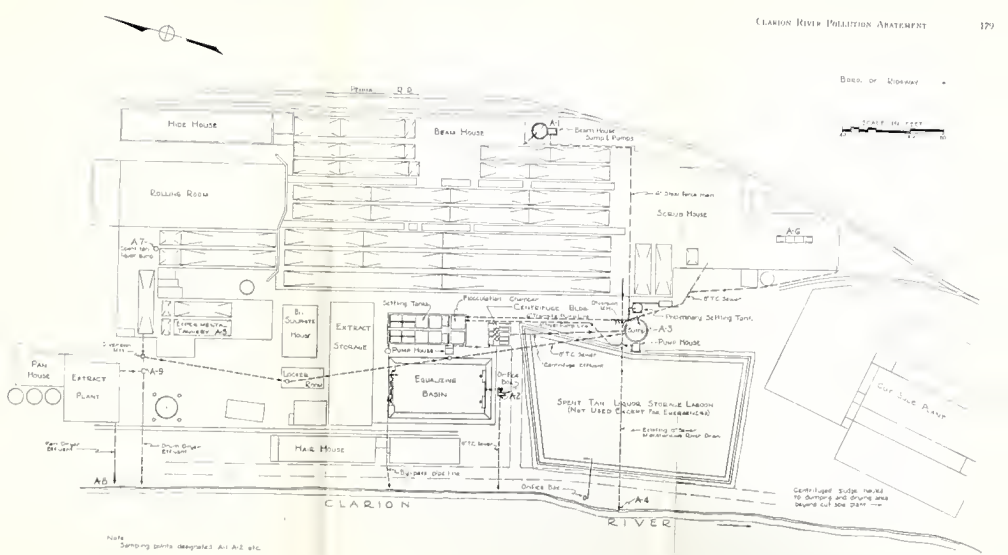

FIGURE 33. EAGLE VALLEY TANNERY EXISTING WASTE DISPOSAL WORKS.

TABLE 25. EAGLE VALLEY TANNERY, RIDGWAY, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEY SAMPLED OCTOBER 12, 1948

Sampling Point	Sample No.	Continuous Time of Discharge: From	To	Total Hours	Average Rate of Discharge: gpm	mgd	Intermittent Batch Disch. Total gpd	Total Daily Discharge mg	Temp °C	5 Day, 20°C BOD: ppm	lbs/day	Total Solids: ppm	lbs/day	% Volatile	Suspended Solids: ppm	lbs/day	% Volatile	Dissolved Solids: ppm	lbs/day	% Volatile	pH	Alkalinity (+) or Acidity (−) to pH 4.50 as CaCO3: ppm	lbs/day	Total Sulfides as S: ppm	lbs/day
Miscellaneous River Drain	A-4	3:00 AM	3:00 PM	12	32 8	0.047		0.024	20	450	90	1,278	256	59 6	546	108	83 6	738	148	41 9	9 20	+ 262	+ 52	1 1	0 2
Waste Disposal Plant																									
Beam House Sump.	A-1	6:30 AM	3:30 PM	9	288	0 415		0 1555	19	916	1,186	10,218	13,232	6 2	4,832	6,257	6 8	5,386	6,975	5 6	11 60	+6,640	+8,590	25 5	33 0
Scrub House Sump.	A-3	6:30 AM	3:30 PM	9	9 75	0.014		0 0527	22	1,684	740	5,380	2,450	76 5	676	297	98 0	4,904	2 160	73 4	2 70	− 700	− 307	0 8	0 4
Soda Ash and Acid Vats	A-6						4,860	0 0019	52	4,615	187	21,338	861	74 0	2,204	89	91 1	19,534	790	72 0	1 64	−4,570	− 182		
Experimental Tannery	A-5						3,930	0 0010		218	9	8,729	291	32 5	538	18	62 8	8,191	272	31 8	1.69	−4,750	− 158		
Total Influent to Plant, Above Box on Effluent Line	A-2	6:00 AM	6.00 AM	24	146	0.210		0 2111	18	1,175	2,122	9,310	16,834	11 7	3,650	6,604	49 3	5,535	10,198	4 5	11 35	+4,305	+7,942	18 5	33 4
								0 2360		551	975	5,312	9,397		860	1,504		4,512	1 893			+1 825	+3 140	2 3	3 8
Reduction by Treatment Plant (Without credit for equalization)																							+4,802		29 6
% Reduction											1,143		7,457			5,157			2,305				60 5%		85 6%
											54 0%		44 2%			77 5%			22 1%						
Reduction by Treatment Plant (With credit for equalization)																							+6,764		32 0
% Reduction											1,756		13,334			6,098			7,238				65 4%		95 9%
											82 9%		79 1%			91 5%			71 9%						
Evaporating Plant																									
Spent Tan Liquor From Eagle Valley Tannery	A-7	(Average discharge for period July 24—Oct. 9, 1948)						0 0126	24	20,020	2,100	37,882	3,950	78 9	6,674	695	89 6	31,258	3,280	75 8	4 70	+1,250	+ 131		
Spent Tan Liquor From Other Tanneries (Avc.)		(Average discharge for period July 24—Oct. 9, 1948)						0 0199		36,550	4,490	50,000	8,300	84 0	13,320	2,530	95 1	31,800	5,770	78 9	4 50	+ 298	+ 49		
Total Spent Tan Liquor Evaporated (Ave.)		(Average discharge for period July 24—Oct. 9, 1948)						0 0325			6,590		12,250			3,225			9,050					+ 180		
Pan Dryer Effluent at River Outfall	A-8	61 hrs in 5 days		12.8	81	0 107		0.057		532	253	958	455	81 6	132	72		806	383		4 33	0	0		
Drum Dryer Effluent at Manhole	A-9	56 hrs in 5 days		11.2	40	0 055		0 017		31	11	1,010	228	2.6	155	35		838	193		5 96	+ 65	+ 15		
Total Discharge to River								0 084			264		683			107			576				+ 15		
Reduction by Evaporating Plant											6,326		11,597			3,118			8,414				+ 165		
% Reduction											95 9%		94 5%			96 7%			93 6%				91 7%		
Total Wastes Produced (During working hours, at this tannery only)								0 2537			4,812		21,090			7,464			13,626				+8,125		33 6
Total Wastes Discharged (during a 24-hour day, including evaporating plant)								0.3180			1,329		10,336			1,719			8,617				+3,207		4 0
Total Reduction (Without credit for equalization)											2,981		10,654			5,745			5,009				+4,918		29 6
% Reduction											69 0%		50 5%			76 8%			36 7%				60 5%		85 1%
Total Reduction (With credit for equalization)											3,592		16,514			6,685			9,939				+6,878		37 0
% Reduction											83 0%		78 4%			89 5%			72 9%				84 3%		95 2%

the Clarion River through drain A-9. The evaporating plant operates for seven or eight 8-hours shifts per week and handles approximately 32,500 gpd of spent tan liquors.

Detailed production figures, and data relating to the operating cost and income from this plant are considered confidential. In general, however, it is acknowledged that the income from this process is sufficient to pay the operating costs with a possible slight excess to help offset overhead and amortization of the first cost. Economic operation of this plant is dependent upon the market for the dried residue from the tan liquors. When the market falls off, the Noxon and St. Marys wastes and possibly those from Clearfield are not accepted, but it is the general policy of the Company to handle the Wilcox and Ridgway spent tan liquors at all times. In the event of a breakdown, spent tan liquors from the Ridgway tannery can be discharged into the spent-tan-liquor storage lagoon shown on Fig. 33. This lagoon has a capacity equal to that of four months' production of spent tan liquors.

Efficiency of Existing Treatment Works

A survey was made of the quantity and strength of the industrial wastes produced at the Eagle Valley Tannery on October 12, 1948, and the results are presented in Table 25. Samples were collected at hourly intervals from each sampling point and analyses were made on the composites. Inasmuch as the various wastes are not combined before treatment is commenced, our engineers sampled the component wastes separately at the beam-house sump, the scrub-house sump, the soda-ash and acid vats in the scrub house and the experimental tannery. Samples were also taken at the effluent orifice box to determine the efficiency of the entire treatment works. Table 25 shows that the preliminary settling tank, flocculators, settling tank and equalizing basin removed 54.0% of the 5-day BOD, 77.5% of the suspended solids, 60.7% of the total alkalinity, and 88.6% of the sulfides. If credit is given for complete equalization in the rate of discharge, the treatment works removed 82.6% of the 5-day BOD, 91.5% of the suspended solids, 85.4% of the total alkalinity and 95.9% of the sulfides. It is of importance to note on Table 25 that the 5-day BOD of the wastes discharged to the miscellaneous drain was 450 ppm, comparable to that of strong domestic sewage. This waste receives no treatment.

The effluent from the pan drier (quadruple-effect evaporator) and drum drier were also sampled, gaged and analyzed as shown on Table 25. It is noted that the pan-drier effluent has a BOD of 532 ppm, or 253 lbs per day. Inasmuch as highly polluted river water is used for cooling purposes in this plant and mixes with the pan-drier condensate, part of this high BOD is attributable to residual pollution in the river water. Our computations show that only 48 lbs per day of the 253 lbs per day measured was due to the river water, and we estimate that the BOD of the condensate alone was 1,330 ppm. The spent tan liquor produced at the Eagle Valley Tannery was found to have a BOD of approximately 20,000 ppm, or for 12,600 gpd a total of 2,100 lbs per day. The difference between the BOD in the influent (from the Ridgway tannery only) and the evaporating plant effluent (from all tanneries) shows an over-all removal of 87.4% of the BOD. The difference between the total BOD of spent tan liquors (6,500 lbs per day from all

tanneries) and the BOD of the evaporating-plant effluent shows that the evaporating plant accomplishes a BOD reduction of about 96%.

Considering the total wastes produced at the Eagle Valley Tannery and the total wastes discharged to the stream, we find an over-all reduction of 69.2% of BOD, 76.8% of suspended solids, 60.5% of total alkalinity and 88.1% of sulfides. When credit is given for the equalizing basin, the efficiencies are increased to 83.0% for BOD, 89.5% for suspended solids, 84.7% for total alkalinity and 95.2% for sulfides.

About 128 lbs of sodium sulfide are used per day in the tannery, corresponding to about 52.5 lbs per day as sulfides. Of this amount, only 4 lbs per day appeared in the final effluents. The tannery uses about 3,680 lbs of lime per day, and if we assume 46% of this amount is removed as at the Wilcox Tannery the final effluent to the river would contain about 3,000 lbs per day of hardness in terms of $CaCO_3$. At drought flow, this amount would increase the hardness of the river by about 18 ppm, an increase which does not appear to be harmful or inimical to the stream.

With respect to odor and appearance, the wastes from this tannery are so thoroughly obliterated by the residual pollution from the paper mill at Johnsonburg that we were unable to determine the effect of these wastes upon the river water. By analogy with the Wilcox Tannery, where the effluent causes no noticeable effect upon the odor and color of the West Branch, and where the quantity and strength of the wastes are larger in proportion to the stream flow than at the Ridgway Tannery, we conclude that the color and odor of the present tannery wastes at Ridgway will have no harmful or inimical effect upon a clear stream, provided that the wastes and stream waters are effectively and instantaneously mixed. To this end it may be necessary at some future date to reconstruct the present outfall sewer so as to discharge into the center of the stream.

Recommendations

Inasmuch as the present increment of BOD loading on the Clarion River at Ridgway does not exceed the allowable increment (see Chapter III) and inasmuch as the present treatment works at the tannery are removing about 83% of the total BOD and 89.5% of the suspended solids produced at the plant, we recommend no higher degree of treatment for removal of organic pollution.

We recommend, however, that a new diversion manhole be built near the scrub-house sump on the miscellaneous drain. This structure should be in the form of an overflow device which will cause all dry-weather flow to be diverted into the scrub-house sump, but allow excessive storm-water run-off to overflow through the existing outlet to the river. The present connection between the beam-house pipeline and the miscellaneous drain should be discontinued so that even during the night no beam-house wastes will be discharged to the stream without primary treatment. With this arrangement it is probable that there will be some discharge to the settling tanks during all periods of the day but any additional flow caused by this arrangement will not overload the capacity of the settling tanks. It is imperative that all wastes except excessive storm-water run-off be passed through the treatment works for effective bacterial disinfection, as explained below. The cost of this proposed improvement will be small.

At some time in the future, when more effective separation of storm water and sanitary sewage is obtained in the borough's sewerage system, the wastes and sanitary sewage now entering the miscellaneous drain should be separated from the storm water in order to avoid altogether the overflows of mixed sanitary sewage and storm water during rainstorms. Such overflows contribute to bacterial pollution of the river.

As at the Wilcox Tannery (See Chapter V) the pH value of the treatment plant effluent is over 11.0 and the total detention period in the settling tank and equalizing basin is about 48 hours; hence effective destruction of coliform organisms and intestinal pathogens should be attained, provided that wastes from all drains are subjected to treatment. When new intercepting sewers for the borough of Ridgway are constructed it is understood that a 10-in interceptor will run along the bank of the Clarion River, through the tannery property. Consideration has been given to reconnecting the sanitary fixtures in the tannery buildings into new drains leading to this sewer, but we do not favor this expensive work as long as effective destruction of intestinal bacteria can be achieved in the present treatment works.

The outlet device from the equalizing basin is intended to provide discharge to the stream at a continuous uniform rate over 24 hours of the wastes produced during the working shift, but the design of the orifice box permits the discharge rate to vary with the head on the orifices. We recommend that the orifice box be remodelled to provide for discharge through a a single constant-head orifice, equipped with a throttling valve for regulation of the rate of discharge.

SINCLAIR AND VALENTINE COMPANY

Description

The newest major industry in the Clarion River basin is the Sinclair and Valentine Company, a national concern which in 1946 established a plant for the manufacture of ink pigments on the banks of Elk Creek at the outskirts of Ridgway, as shown in Fig. 1. The Company employs about 50 persons, most of whom work an 8-hour shift, 5 days a week, although some activities require 18 hours per day for a full 7-day week. Water is obtained from the borough's system at the rate of 1 to 2 mg per month, of which an estimated 50,000 gpd is process water, the remainder being used for the boilers and sanitary purposes. Sewage and wash waters from the sinks and showers are discharged directly to Elk Creek as shown in Fig. 34.

Inasmuch as the processes used at this plant and the type of wastes produced are quite different from any other plant in the Commonwealth of Pennsylvania (to the best of our knowledge), they will be explained in considerable detail. In general, pigments are formed by carefully controlled mixing of two solutions, the first containing diazotized dyestuffs and the other containing precipitate-forming salts. The dyestuffs, which are bought or in some cases produced by the plant depending upon their complexities, are mixed with either water, or solutions of caustic or acid, in separate vats. The plant uses about 33,000 lbs of dye-stuffs per month comprising tobias acid, metanitroparatoluene, eosin, methyl violet, erioglaucine, dichlorobenzidene, rhodamine, brilliant green, thioflavine, Victoria blue paranitroaniline and Orange II. In other vats, the precipitate-forming salts, acids or hydroxides are made into solutions depending upon the particular color demands.

Complementary pairs from the two types of vats are then quickly coupled and mixed under controlled temperature conditions. In the common mixing vat, the solutions produce a precipitate of the desired color and the mixing continues until sufficient time has elapsed for the reactions to become developed and completed. The solution is then pumped to filter presses where the precipitate is separated from the solution and then further washed to remove unwanted salts. The filtrate and the wash waters are drained to ditches which discharge through a common pipe to the lagoon shown on Fig. 34. Sometimes the filter presses leak and allow considerable precipitate to pass into the drains.

The clay-like residue on the filter presses is then scraped and put into trays for final finishing in one of three ways. The most common finished product is powder which is produced by drying the precipitate in ovens and pulverizing it. About 97,000 lbs of dried powder is shipped per month in wooden or cardboard drums. Another type of finished product results when the dry lumps from the oven are saturated with a varnish vehicle and the resultant mixture is then passed through rollers which press the varnish into the ink mass to form a paste. This type of finished product is seldom used because of its relatively expensive processing. The third type of ink shipment is formed by taking the ink clay as it comes from the filter presses and putting it in a vacuum drum, where varnish under pressure is applied to the clay, forcing all of the entrapped water out of the clay. The water driven off in the drum is drained to the lagoon. The vacuum drum is thoroughly cleaned out at the addition of each different ink color. About 43,000 lbs of this type of paste are produced per month and shipped in steel drums.

Suspecting the presence of toxic substances in some of these wastes, we investigated the types and quantities of compounds other than dye-stuffs used at this plant. According to the plant manager, the following compounds only are used: acetic, hydrochloric, nitric, sulfuric and tannic acid; aluminum, barium and calcium chlorides; lead and sodium acetates; sodium and disodium phosphate; aluminum sulfate; sodium bicarbonate, carbonate, hydroxide, molybdate, nitrite and tungstate; lead nitrate; beta naphthol; and parachloro-orthonitroaniline. Cyanides, chromium, mercury, copper, phenol and other such toxic compounds are not employed. The absence of bactericidal substances in the wastes is attested by the fact that BOD results of the plant effluent and lagoon effluent were readily obtained without excessive dilutions. The BOD in the effluent results in part from the organic dyes and in part from such substances as acetic acid, acetates, tannic acid, naphthol and analines.

Efficiency of Existing Treatment Works

Samples were taken of the influent and effluent at the lagoon on November 3, 1948, and the rate of effluent from the lagoon was measured at 15-minute intervals. The results of these analyses are shown in Table 26, along with a summary of analyses by the Pennsylvania Department of Health on September 29, 1947 and December 4, 1947, shortly after the lagoon was constructed. These analyses show considerable variations in the characteristics of the influent and the effluent on the three dates of sampling. In general, it is noted that the BOD of the influent is comparable to that of domestic sewage and that approximately 60% of this BOD is removed in the lagoon. It is also noted that about 60% of the total volatile

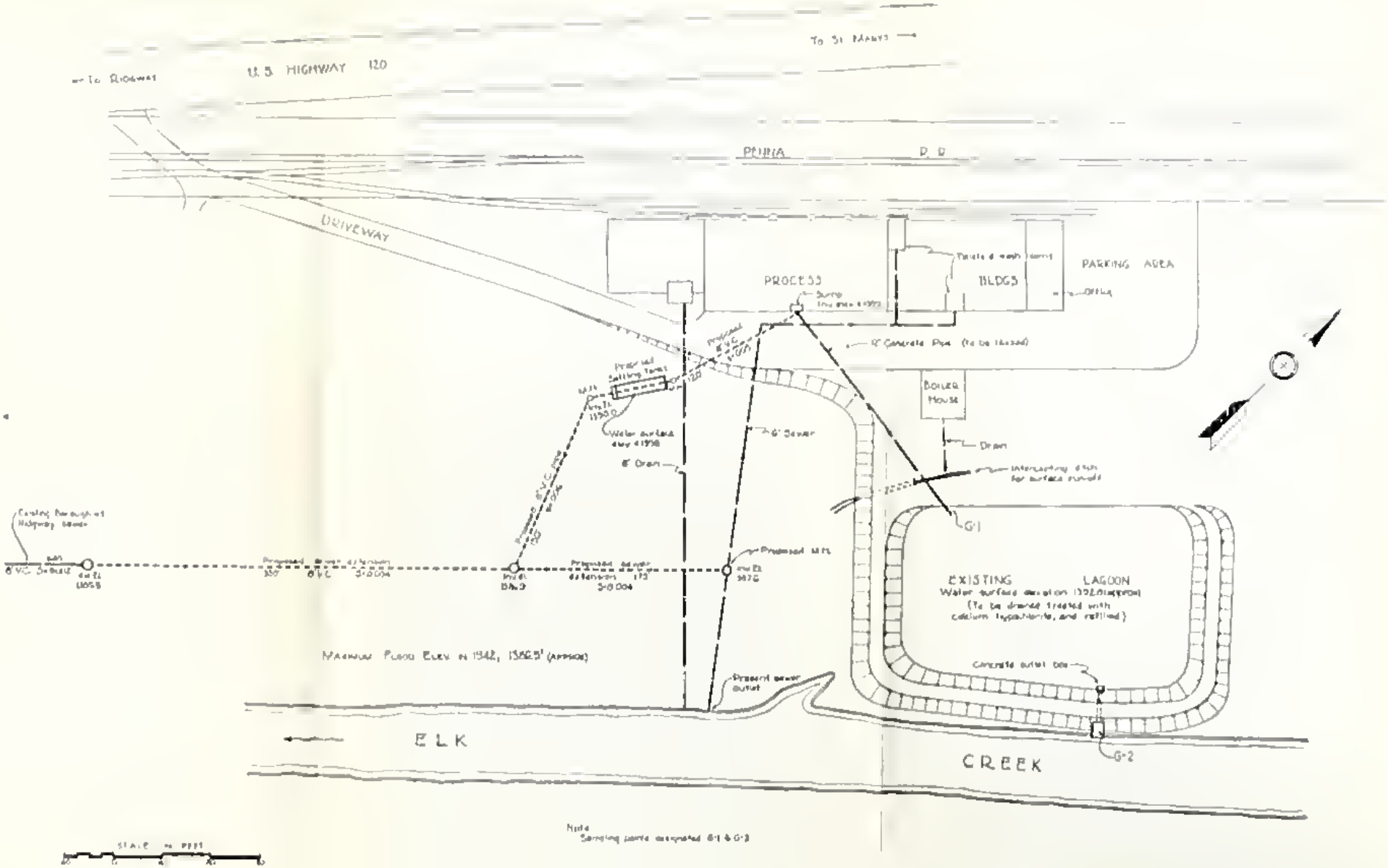

FIGURE 34. SINCLAIR & VALENTINE COMPANY EXISTING WASTE DISPOSAL WORKS AND PROPOSED IMPROVEMENTS.

TABLE 26. SINCLAIR AND VALENTINE COMPANY, RIDGWAY, PENNSYLVANIA. SUMMARY OF INDUSTRIAL WASTE SURVEYS

Analysis	*Camp, Dresser & McKee November 3, 1948*			*Penn. Dept. of Health September 29, 1947*			*Penn. Dept. of Health December 4, 1947*		
	Lagoon Influent	*Lagoon Effluent*	*% Removal*	*Lagoon Influent*	*Lagoon* Contents*	*% Removal*	*Lagoon Influent*	*Lagoon* Contents*	*% Removal*
Temperature, °C	14 to 41	14	....	....	....	....	....	....	....
Color, ppm	....	....	....	2,000	500	75.0	10,000	2,000	80.0
Turbidity, ppm	....	....	....	320	30	90.6	1,400	200	85.7
pH	8.3	7.1	....	6.1	6.2	....	5.3	5.3	....
Methyl-orange Alkalinity, ppm	440	194	55.9	60	86	−43.3	320	160	50.0
5-day, 20°C BOD, ppm	238	100	58.0	....	25	....	640	240	62.5
5-day, 20°C BOD, lbs per day	....	45	....	....	....	....	....	....	....
Total Solids, ppm	3,140	2,236	28.1	3,560	980	72.5	9,980	2,780	72.1
Total Fixed Solids, ppm	2,502	1,977	21.0	3,210	720	77.6	8,600	2,300	73.2
Total Volatile Solids, ppm	638	259	59.4	350	260	25.7	1,380	480	65.2
Suspended Solids, ppm	450	77	82.9	260	60	76.9	720	80	88.9
Suspended Fixed Solids, ppm	250	43	82.8	200	20	90.0	320	40	87.5
Suspended Volatile Solids, ppm	200	34	83.0	60	40	33.3	400	40	90.0
Dissolved Solids, ppm	2,690	2,159	19.7	3,300	920	72.1	9,260	2,700	70.8
Dissolved Fixed Solids, ppm	2,252	1,934	14.0	3,010	700	76.7	8,280	2,260	72.7
Dissolved Volatile Solids, ppm	438	225	48.6	290	220	24.1	980	440	55.1
Lead, ppm	....	....	....	0	0	....	150	0	100.0
Sulfates, ppm	....	....	....	....	....	....	4,600	100	97.8
Acetates, ppm	....	....	....	....	....	....	465	112	75.9
Chlorides, ppm	....	....	....	....	....	....	1,800	825	54.2
Rate of discharge, gpd	....	53,900	....	88,000	....	....	....	....	....

*There was no overflow from the lagoon at the time of this study. Surface samples were taken near the effluent discharge box.

solids are reduced, thereby indicating that biological action is taking place in the lagoon.

The lagoon was originally constructed of a pervious cinder embankment, apparently with the expectation that much of the liquid in the wastes would seep into the stream. In October of 1948, however, the dike was further strengthened and rendered tighter by a layer of clay on the interior bank. In adding this clay to the dike, the bulldozer operator inadvertently caused the dike to erode and the entire liquid contents were discharged suddenly to the stream. This sudden shock load of wastes killed a great number of fish in Elk Creek between the plant and the mouth of the creek, which led to the suspicion that the wastes contained toxic substances. Considering the volume and BOD of wastes in the lagoon, and the low stream flow at that time, it can be seen that the fish would be killed by lack of oxygen alone. It is also suspected that their gills were coated with pigment washed from the bottom of the lagoon. It has been reported that some of the injured fish were taken from the stream, kept in clean water and later returned to the stream with apparently no ill after-effects. It is our opinion, therefore, that the fish-killing action of the sudden lagoon discharge was due not to toxic substances but to lack of oxygen and the encrusting of paint pigments.

Although the Pennsylvania Department of Health analyses of 1947 showed a decided decrease in color between the lagoon influent and the lagoon contents, our observations in 1948 indicated quite the opposite. The color of the influent, sampled at 15-minute intervals, changed from pink to blue, to orange, to lavender, to green and back through this cycle several times. All of the samples seemed to have a red pigmentation and a greenish sheen. The effluent from the lagoon, however, had a much deeper green color, without the presence of the red precipitate. That there should be an intensification of green color in the lagoon can readily be explained. The plant uses considerable eosin, which is brominated flourescein ($C_{20}H_8Br_4O_5$). This dye is generally precipitated with lead salts and when this solution is discharged to the lagoon, the presence of sodium sulfate in the lagoon causes the formation of lead sulfate and the reconversion of the compound to eosin, which then loses its bromine ions by decomposition to form flourescein ($C_{20}H_{12}O_5$). This theory is substantiated by the fact that filtered plant influent has a much lower intensity of flourescein color than does the lagoon effluent. With respect to color, therefore, the lagoon is actually a detrimental treatment works.

Investigation of Treatment Methods

The BOD loading from the untreated wastes at this plant is only about 100 to 200 lbs per day and the wastes do not appear to be toxic. Hence, the only problems of pollution result from the color and solids content of the wastes. The present lagoon removes a high proportion of the suspended-solids content of the waste but intensifies the flourescein color. To determine the best way to remove the solids from the waste and to neutralize the effect of the color upon the stream, we made a series of experiments which are described below.

Settling tests were conducted of the raw wastes and indicated that from 50 to 70% removal of the suspended solids could be obtained at overflow rates of about 600 gpd per sq ft. By way of comparison, the present lagoon removed 82.9% of the suspended solids on November 3, 1948 with an over-

flow rate of about 1.5 gpd per sq ft. With an efficiently designed rectangular sedimentation basin, therefore, we expect that about 70% of the suspended solids would be removed, with a detention period of two hours or less. We found, furthermore, that the sludge so produced had a relatively high-solids content, (about 5%) and hence we estimate that approximately 300 cu ft of sludge would be produced per week.

With respect to color removal, we found the effect of pH upon the color of the lagoon effluent to be as follows:

ph	*Description of Color*
12.00	dark salmon
11.40	dark green
7.70	dark blue-green
1.20	moderate apple-green
0.90	light apple-green

These tests show that acidification or alkalinization will change the color but may have very little effect upon the intensity of color. The effect of chlorine upon the color intensity, after a contact period of 20 minutes, is indicated by the following table:

Chlorine dosage in ppm	*Color removal in %*
100	60
150	70
200	75
250	80

These tests indicate that the flourescein color can be reduced by high dosages of chlorine. It is understood that the chemists in the Sinclair and Valentine Company plant have conducted experiments with excessive dosages of chlorine and obtained complete bleaching action. On the basis of a flow of 50,000 gpd and a chlorine dosage of 250 ppm, the chlorine requirement would be approximately 100 lbs per day and the cost about $10 per day.

Activated charcoal was found to remove the color completely and it is probable that effective color removal could be obtained by passing the effluent from the lagoon through a bed of activated charcoal.

It was observed that while the lagoon effluent had a marked color effect upon Elk Creek, this color was entirely dissipated and never evident in the Clarion River. On the basis of that observation we felt that it might be wise to have the Sinclair and Valentine Company effluent accepted into the borough's sewers and discharged into the Clarion River below Ridgway after treatment with the borough's sewage. An experiment was conducted to determine the extent to which the ink-plant raw wastes would discolor the borough's sewage, the results of which are as follows:

% of Sinclair and Valentine Company's wastes by volume in Ridgway sewage	*Appearance of mixture of waste and sewage*
0	light grey color
5	very slight green tinge
10	slight green color
20	distinct green color

We estimate that the percentage of ink plant wastes in the borough's sewage will vary from 5 to 10% and consequently give a slight green discoloration to the sewage. This color should in no way interfere with biological treatment of the borough's sewage and upon discharge of the combined wastes to the Clarion River below Ridgway there should be no evidence of pollution by color.

Recommendations

We recommend that the present method of waste disposal by lagoon be discontinued and in lieu thereof that two new covered rectangular sedimentation basins be constructed to remove settleable solids and that the effluent therefrom discharge to the borough's sewers. Each of the two settling basins should be 40 ft long x 4 ft wide with a depth of flow of 5 ft. Covers should be provided for protection against freezing over week-ends in cold weather. At the average rate of flow of 50,000 gallons per 16 hours, the overflow rate for one basin would be 468 gpd per sq ft and for both basins in parallel, 234 gpd per sq ft. For one basin, the theoretical detention period would be 1.92 hours and for both basins 3.83 hours. At an estimated peak flow of 125,000 gallons in 16 hours, the overflow rate for one basin in operation would be 1,170 gpd per sq ft and for both basins 586 gpd per sq ft, the corresponding theoretical detention periods being 0.77 hours and 1.53 hours respectively. While one basin might well handle the average load, we recommend that both basins be built in order that one may be taken out of service for cleaning. We propose that the basins not be equipped with sludge-removal mechanisms but that arrangements be made by means of a swivel-jointed pipe to decant the contents of one basin at a time and that the accumulated sludge be shoveled by hand into barrels for the recovery of a salable by-product. One basin should be cleaned each week. We estimate that approximately 800 lbs of pigment per week will be recovered (on a dry basis) and that this pigment can be used in making a low-grade paint product.

The effluent from the proposed settling tanks should then be led as shown on Fig. 34, through an 8-in vitrified clay sewer into the proposed municipal sewer extension as indicated on a plan of the present and proposed sewers of Ridgway, prepared by C. Keeler Gifford and dated March, 1946.

At the present time the sanitary wastes from the Sinclair and Valentine Company plant are discharged without treatment into Elk Creek. It will be necessary, therefore, that these wastes be intercepted and conveyed to the nearest borough sanitary sewer. This flow can be carried through the same sewer as the settled industrial wastes, as indicated on Fig. 34.

We estimate that the entire construction cost of the necessary 8-in. sewer lines and the proposed settling tanks will be $12,500 and the annual cost of operation and maintenance will be small. When a sewage treatment plant is constructed for the borough of Ridgway, the Sinclair and Valentine Company should be assessed an equitable charge on the same basis as other water users and contributors to the sewerage system.

BOROUGH OF RIDGWAY

Discussion

The borough of Ridgway is the county seat of Elk County and a center of diversified industry. In addition to the aforementioned Eagle Valley Tannery and the Sinclair and Valentine Company, there is a power plant, an

electric-equipment manufacturing plant, and a large wood-working mill, none of which are reported to produce liquid industrial wastes. The population of the borough was relatively constant at about 6,200 from 1920 to 1940 and the present population is estimated at 7,000 persons.

The sewers of Ridgway were originally planned on the separate system, but unlike St. Marys, this plan has not been rigidly followed. It is reported that many roof drains discharge to the sanitary sewers and that during rainstorms many of the sewers are surcharged. Most of the residential area in the borough limits is served by sanitary sewers and about 70% of the sewage was originally discharged through a 20-in outlet into the Clarion River about 1,500 ft downstream from the Main Street bridge. Much of this sewage now discharges into Elk Creek near its mouth. There are five or more other outlet sewers which serve about 1,500 persons and discharge to Elk Creek or to the Clarion River.

In May, 1938, Gascoigne & Associates of Cleveland submitted a report recommending a system of intercepting sewers to collect and convey all sanitary sewage to a point on the north bank of the Clarion River opposite a treatment plant site on the south bank about one mile downstream from the Main Street bridge. They further advocated that roof water be excluded from all future sanitary sewers, but to allow for present storm-water run-off they proposed to intercept only three times the dry-weather flow and to allow all flows in excess thereof to overflow into the river.

On February 21, 1945, the Sanitary Water Board directed the borough to submit, not later than December 31, 1945, a report on the existing sewer system and detailed plans for intercepting sewers and works for complete sewage treatment. On the basis of these plans, the Sanitary Water Board on October 22, 1947, authorized the issuance of a permit for complete sewage treatment works, subject to certain provisions, and reminded the borough that a financial program should be prepared in anticipation of an order from the Board requiring construction of the works.

The proposed treatment works were designed for a population of 8,000 persons and comprise a 16-in cast-iron pipe under the Clarion River at the terminus of the proposed intercepting sewers; a pump station with a bar rack, metering device, laboratory and office; an Imhoff tank providing a detention period of 2 hours and an overflow rate of about 700 gpd per sq ft, at a flow of 1 mgd, with a sludge digestion compartment of 3.5 cu ft per capita; duplicate 12-in dosing siphons; two low-rate trickling filters with provision for recirculation of part of the effluent to maintain adequate discharge through the Imhoff tank during periods of low flow, the filters being designed for a loading of 550 lbs of BOD per acre ft and a dosage of 3.85 mgd per acre; four intermittent sand beds of 5,500 sq ft each to remove suspended solids from the trickling filter effluent; and chlorination of the final effluent. During wet months, the engineers proposed to discontinue operation of the filters and intermittent sand beds so as to afford only primary settling followed by chlorination.

Recommendations

The studies of the assimilative capacity of the Clarion River at Ridgway, as described in Chapter III, show that the BOD loading from the present industrial wastes and settled sanitary sewage at Ridgway is not sufficient to cause pollution of the river even during drought flows, but that bacterial

pollution will be excessive unless all sewage is effectively chlorinated. Hence, any treatment of the borough's sewage in excess of primary sedimentation, the removal of scum and screenings, and disinfection of the effluent, is superfluous. We recommend, therefore, that construction of the portion of the proposed borough treatment works required for secondary biological treatment, i.e. the trickling filters and sand beds, be deferred until such future time as the need therefor is demonstrated. We estimate that approximately $114,000 of the cost of the treatment works will thus be saved.

In designing the treatment plant, the engineers planned to take the sanitary sewage from all industries, but to exclude all major process wastes such as those from the Eagle Valley Tannery and the Sinclair and Valentine Company. At the request of the tannery's engineer, some consideration was given to taking the effluent from the tannery treatment works, but inasmuch as detailed plans for the works were almost completed at the time, the consulting engineers pursued the matter no further. Inasmuch as the degree of treatment now afforded the tannery wastes is adequate, inasmuch as the sanitary sewage at the tannery will be adequately treated after our recommendations for the tannery are adopted, and inasmuch as tannery wastes will raise the pH of the borough's sewage and thereby inhibit bacterial action and sludge digestion, we recommend that the tannery process wastes and sanitary sewage be excluded from the borough's sewers.

As stated hereinbefore, we recommend that after primary sedimentation the Sinclair and Valentine Company process wastes be accepted into the borough's sewers for the purpose of preventing color pollution of Elk Creek. These wastes should in no way interfere with the treatment of the borough's sewage and the slight greenish discoloration of the mixed raw wastes should produce no noticeable effect upon the treatment plant or the Clarion River. Sanitary sewage from the Sinclair and Valentine Company plant should also be accepted into the borough's sewers.

CHAPTER IX.

POLICING AND CONTROL OF WATER QUALITY BY SANITARY WATER BOARD

The effective control of pollution requires not only that adequate works and facilities be constructed for the removal of the pollutants but that these facilities be operated continuously and satisfactorily at all times. In our judgment pollution abatement in the Clarion River basin depends to a far greater extent upon the proper and continuous use of the facilities provided for pollution abatement than it does upon the availability of adequate facilities. It is essential, therefore, after the works recommended in this report have been constructed, that the Sanitary Water Board have effective means for insuring the continuous and satisfactory use of these works. Periodic inspections and river sample analyses will not suffice because of the probability of sporadic overflows or dumpings of strong industrial wastes.

In the case of the Clarion River, organic pollution is of paramount concern and the damage which may be expected from clandestine dumping or overflows of organic pollutants is measurable in terms of the oxygen concentration in the waters of the river. This fact suggests the continuous recording of the oxygen concentration at one or more critical points in the river so as to determine when and to what extent damage has been done by sporadic pollution and to determine the source of the pollutants.

It is possible with equipment which is commercially available at the present time to develop the design for and construct stations for the continuous recording of the dissolved-oxygen content of the river waters. One type of equipment which might be used for this purpose employs a polarograph with a dropping mercury electrode. We recommend specifically that the Sanitary Water Board authorize the development and installation of one or more automatic stations for the continuous recording of the dissolved-oxygen content in the Clarion River. Such stations should be owned and operated by the Commonwealth. We recommend that the first station be located about three miles below Johnsonburg. This station might also contain equipment for the continuous recording of pH and possibly of turbidity.

Our studies indicate that after the works recommended for construction by the New York and Pennsylvania Company are completed and in operation, the oxygen content of the Clarion River water should at all times exceed 2 ppm at the proposed recording station without the East Branch dam in operation and should exceed 5 or 6 ppm when low-flow dilution is provided by the East Branch dam. Organic pollution will be indicated therefore if the oxygen content drops below these levels. Excessive organic loading of the stream may exist, however, at higher stream flows without detection by the oxygen recorder. The effectiveness of the oxygen recorder in the detection of pollution is limited therefore to periods of low flow or to heavy slugs of organic matter.

From a legal viewpoint, low oxygen contents per se do not constitute

pollution. Low oxygen levels are indirect evidence of pollution by organic matter but not direct proof thereof. In order to have proof of organic pollution it will be necessary to have BOD analyses which show organic contents in excess of the allowable loading established for the stream. To detect sporadic pollution loads, analyses must be made at the time the organic matter flows past the sampling station. Continuous recording of BOD is therefore indicated.

Development of Continuous Recorders

Satisfactory apparatus for the continuous recording of BOD is not now commercially available. In our judgment, however, enough is known at present about the principles involved to develop a suitable apparatus for this purpose. We recommend, therefore, that the Sanitary Water Board authorize a research program directed toward the development of satisfactory continuous recording apparatus for BOD. We further recommend that the oxygen-recording station to be first constructed by the Sanitary Water Board on the Clarion River be designed with sufficient space to accommodate the equipment to be developed for continuous recording of BOD. It is contemplated that the dissolved-oxygen-recording apparatus will be a part of the BOD-recording apparatus.

It is recommended that the Sanitary Water Board proceed with plans for an oxygen-recording station to be located on the Clarion River about three miles downstream from Johnsonburg so as to have this station ready for operation as soon as the pollution abatement facilities recommended for the New York and Pennsylvania Company are in operation. It is further recommended that, pending the development of suitable recording apparatus for BOD measurements, the Sanitary Water Board assign one full-time technician to the oxygen-recording station for the purpose of making determinations of BOD on river samples every day.

In order to prove that BOD pollution found at the proposed oxygen-recording station originates at Johnsonburg, it will be necessary to show that the pollution was not present in the East and West branches of the Clarion River upstream from Johnsonburg. This may ultimately require BOD recording stations on both branches upstream from Johnsonburg. Such stations are not recommended, however, until evidence is at hand to indicate that the necessary proof cannot be obtained from sanitary surveys and the routine analyses of samples collected in the branches.

The recommendations contained in this chapter are of paramount importance, not only for the Clarion River, but for all other streams where pollution is caused by organic industrial wastes. A large part of the cost of the research and development required to obtain satisfactory recording of BOD and dissolved oxygen is properly chargeable against the entire statewide pollution abatement program.